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RAILWAY GAUGES, (1)

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(*Continuation.*)

Figs. 11 to 16, pp. 107 to 117.

PART II.
THE TRANS-SHIPMENT PROBLEM.

TABLE OF CONTENTS.

CHAPTER VIII. — BREAKING BULK AT TRANS-SHIPPING STATIONS.

On principle, objection may always be raised against the employment of different gauges for railways in the same country — this objection is due to the difficulties caused by trans-shipment at the trans-shipping stations.

(1) See *Bulletin of the Railway Congress*, January 1924, p. 25

But if further investigation is made into the goods which are the subject of trans-shipment it will be seen that the difficulty is often only slight because it does not affect loads which do not fill a wagon and which need to be trans-shipped in any case.

In our opinion, the main disadvantage is that of the maintenance of the rolling stock, of two different gauges, in readiness for the same goods or the same passengers. This loss of efficiency is difficult to put into figures and it would be necessary to investigate its magnitude in each individual case. Most frequently it is not very great, as compared with the service that could have been attained from the rolling stock if it had all been of the same gauge. The same applies to the extra space that must be kept clear in the stations on this account.

However this may be, the magnitude of the trans-shipment varies according to the classes of lines that meet, and we may divide these into three groups :

I. — Trans-shipment between two classes of main line, the one of broad gauge serving an area that has already been opened up, and the other of narrower gauge running into new areas to be developed;

II. — Trans-shipment between secondary lines and main lines in areas that have been opened up, or between secondary lines in areas that have been opened up in new countries and the main lines of such areas;

III. — Trans-shipment between lines of different gauges in countries where the railway system is fully developed.

The first case is that which occurs where trans-shipment is necessary between feeder lines and the main lines in new countries; the second is that which is found between secondary and main lines of railway in Belgium; and finally the third is that which is found at some frontiers of countries or at the ends of railway systems when the tracks of the two railway systems in question are laid to different gauges, as for example at the Franco-Spanish frontier or at the Russo-German frontier. We will examine these three cases separately.

I. — EXCHANGES BETWEEN FEEDER LINES (OF NARROW GAUGE) AND THE MAIN LINES (OF BROADER GAUGE) IN NEW COUNTRIES.

The disadvantages which result from exchanges of this kind are small. The fact must not be lost sight of that the distances covered are long and are run over at slow speed on the feeder line, and sometimes also on the other, and that the increases in cost or in length of time taken which may result from this trans-shipment are negligible when compared with the total cost and time. They are, moreover, largely compensated for by the advantage that results from the lower capital charge per mile in the new areas.

The following is a concrete example showing how greatly the magnitude has been exaggerated of the supplementary expenditure arising from change of gauge for lines of these classes :

The journey from Itapura to Santos, in Brazil, comprises 436 km. (271 miles) of metre gauge track between Itapura and the town of São Paulo, followed by 79 km. (49 miles) of broad gauge thence to the port of Santos. The breaking up of a load causes a loss of time of only two hours at a place at which it would under any circumstances have been necessary to make up the trains afresh, and the pre-war cost was about 27 centimes per ton. This amounted to 1/300[th] of the total cost and to 1/39[th] of the time, that is to say 0.33 % of the freight cost and 2.6 % of the time.

The following is another example taken

from the annual reports of the *Sorocabana Railways* of which the metre-gauge system has three trans-shipping stations where it joins the broad-gauge *São Paulo Railway* : at São Paulo, at Jundiahy and at Barra Funda. (See table 40.) Exchanges are also made at Jundiahy with the *Paulista Railway* of which the gauge is the same as that of the *São Paulo Railway*, that is 1 m. 60 (5′ 3″).

TABLE 40.

YEARS.	Trans-shipments between the Sorocabana and the São Paulo railways.									Trans-shipment with the Paulista Railway at Jundiahy.
	At São Paulo.			At Barra Funda.			At Jundiahy.			
	English tons.	Reis per ton.	Centimes.	English tons.	Reis per ton.	Centimes.	English tons.	Reis per ton.	Centimes.	English tons.
1908	60 197	206	33	8 958	279	45	13 216	147	24	2 957
	5 578	...	...	9 472	...	...	9 155	...	...	46 000
1909	82 296	169	27	7 101	268	42.5	16 948	106	17	2 363
	8 034	...	...	19 967	...	...	7 622	...	...	91 000
1910	53 283	229	37	9 671	248	40	15 797	107	17	3 410
	8 477	...	...	25 930	...	...	7 653	...	...	873

The trans-shipment, which was much smaller, between the *Sorocabana* and the *Paulista Companies'* lines was rated uniformly between the companies at 800 reis per ton, that is 1.28 francs per ton (in all the changes of currency value we have taken the milreis at 1.60 francs).

The lower rate that can be charged per mile owing to the use of tracks of narrower gauge in outlying areas makes it possible to pay interest on the capital invested in such undertakings, which often could not have been carried through if it had been necessary to construct them under the same conditions as the lines of the already developed areas.

From this it must be concluded that a break of gauge at the outskirts of the developed areas only causes slight disadvantages from the point of view of the total result required to be obtained. The stations where change of gauge occurs play to some extent an analogous part to that of those stations from which a single line is doubled when it enters an area having heavier traffic.

II. — EXCHANGES BETWEEN MAIN AND LIGHT RAILWAYS IN COUNTRIES WHERE THE RAILWAY SYSTEM IS FULLY DEVELOPED.

In this case the problem appears in a different form. The light railway is usually of comparatively short length which is not the case on the main line; and the cost of trans-shipment is much greater in proportion to that of the total.

If we represent by :

l, the length in miles of the feeder line under consideration;

f, the cost of carriage per ton-mile on such a line;

F, the cost of carriage per ton-mile on the broad-gauge line (4′ 8 1/2″ in the countries that have adopted this gauge); and

P the cost of trans-shipment per ton, then the total freight from the end of the light railway, including reloading on to the wagon of the main line will be : $(fl+P+a)$, where a is the total of the standing charges (booking, etc.).

If, on the other hand the light railway had been replaced by a branch of the main line the freight would have been $(Fl+a)$. For an annual tonnage T, the total freights would have been respectively $T(fl+P+a)$ and $T(Fl+a)$. The term T, which is common, may be disregarded.

Now if the narrow gauge had not been adopted, it would have been possible to expend TP francs more for the line, that is $\frac{TP}{l}$ francs more per kilometre, which represents the interest on $\frac{100+P}{ln}$ francs at n %, and trans-shipment would have been avoided.

The financial success of the undertaking can be estimated by the comparative value of $Tfl - TFl$, and the freight per axle. The general conclusion to be drawn is that the gauge that should be adopted depends on the conditions and must be investigated for each particular case.

There is however, one matter which is of importance and which applies to the case when the light railway is constructed of the same gauge as the main line to which it is connected. It fairly often happens, however paradoxical this may seem, that trans-shipment takes place nevertheless. This is because the vehicles on mixed service generally run over a much greater distance on the main line than on the light railway and frequently the latter may be robbed of its rolling stock unless it is equipped in a manner disproportionate to its requirements. It follows then that the light railway prefers to cease running the vehicles of the main line over its system, and it is to its advantage to use its own rolling stock. This case occurs sometimes even at exchange stations between main lines of railway.

III. — EXCHANGES ON THE MAIN LINE OF THE SAME RAILWAY SYSTEM OR BETWEEN TWO MAIN RAILWAY SYSTEMS LAID TO DIFFERENT GAUGES.

It is necessary that the use of different gauges should be avoided on two sections of the same railway system both situated in a developed area or between two adjacent railway systems in two areas both of which have been developed. There are, however, some breaks of gauge of this kind, particularly at some of the European frontiers, and there will be others shortly in countries overseas when the railways have reached their common frontier. This has already occurred in Australia, in British India and on the Brazil-Uruguay frontier.

It must not be concluded at once that it is necessary to change the gauge of one of the two railway systems or of both. If this class of break of gauge is to be condemned and should have been avoided, this is no reason for its magnitude to be exaggerated. Moreover breaks of load actually occur at various points with all transport : at the start where the goods are placed in lorries; at the departure station where they pass from lorry to goods wagon and conversely at the arrival station. There are also trans-shipments at seaports. Now if we except the loading in bulk of coal, wheat, minerals, etc., there are few installations that enable trans-shipment to be avoided from lorries to wagons and *vice versa* or between wagons and ships; and before making involved calculations regarding a radical change of gauge, of which the financial charge would weigh heavily on the working, it is necessary to investigate whether internal improvement cannot be made on the railway system itself, by increasing

TABLE 41. — **Table of railways having systems with two gauges.**

Mileage on the :	RAILWAYS.	Kilo-metres.	Gauge.	Kilo-metres.	Gauge.	Original companies.
	EUROPE.					
1.1.1921	Italian (State)	15 670	1 m. 445	542	0 m. 950	
—	Norwegian (State)	1 910	1 m. 435	910	1 m. 067	
—	Portuguese (Minho & Douro Railway	362	1 m. 670	161	1 m. 000	
1.1.1912	Russian (State) Northern Railway	2 296	1 m. 524	840	1 m. 067	
—	Russian (Moscow-Kieff-Voroneje)	1 960	1 m. 524	500	1 m. 000	
—	Russian (Riasan-Uralsk Railway)	3 803	1 m. 524	590	1 m. 000	
—	Russian (Warsaw-Vienna Railway)	492	1 m. 435	258	1 m. 524	
1.1.1921	Serbian (State) Railway	940	1 m. 435	477	0 m. 760	
	ASIA.					
1.4.1921	Madras & Southern Mahratta Railway	1 735	1 m. 676	3 137	1 m. 000	(1 078 m. and 1 949 m.). Madras Railway. East Coast Railway.
—	Nizam's Guaranteed State Railway	569	1 m. 676	623	1 m. 000	(354 m. and 575 m.). Hyderabad & Godavari Valley Railway.
—	North Western Railway of India	8 050	1 m. 676	...	0 m. 760	(5 002 m.).
—	South Indian Railway	724	1 m. 676	2 096	1 m. 000	(450 m., 303 m. and 98 m.).
		...	...	158	0 m. 760	Madras Railway.
—	Bengal Nagpur Railway	3 055	1 m. 676	1 172	0 m. 760	(1 898 and 728 miles).
—	Bombay, Baroda & Central India Railway	1 622	1 m. 676	2 941	1 m. 000	(1 008 m., 1 827 m. and 29 m.). Cawnpore & Achmera Railway.
		...	...	47	0 m. 760	Rajputana Malwa Railway.
—	Eastern Bengal State Railway	2 599	1 m. 676	1 805	1 m. 000	(1 615 m. and 1 122 m.). North Bengal Railway. Dacca State. Assam Behar. Cooch Behar, etc.
—	Ceylon (State) Railway	983	1 m. 676	179	0 m. 760	(611 m. and 111 m.)
1.1.1922	Siam (State) Railway	998	1 m. 435	1 231	1 m. 000	
1.1.1912	Damascus-Hamah Railway and extensions	250	1 m. 050	453	1 m. 435	

TABLE 41 (*continued*).

Mileage on the :	RAILWAYS.	Kilo-metres.	Gauge.	Kilo-metres.	Gauge.	Original companies.
	AFRICA.					
1.1.1922	Algerian (State) Eastern Railway	806	1 m. 450	147	1 m. 000	
—	Algerian Bona-Guelma Railway	320	1 m. 450	128	1 m. 000	
—	Western Algerian Railway	380	1 m. 450	227	1 m. 050	
—	Tunisian Bona-Guelma Railway (1)	498	1 m. 450	1 055	1 m. 000	
—	Egyptian (State) Railway	2 478	1 m. 435	222	1 m. 067	
	NORTH AMERICA.					
	Denver & Rio Grande Railway	...	1 m. 435	...	0 m. 910	
1.1.1922	Mexican National Railway	10 409	1 m. 435	623	0 m. 910	
	SOUTH AMERICA.					
1.1.1921	Central of Bzazil (State) Railway (2)	1 110	1 m. 600	1 265	1 m. 000	Various.
		...	..	64	mixed	
—	Dourado Railway (2)	149	1 m. 000	124	0 m. 600	
—	Western of Minas (State) Railway (2)	1 564	1 m. 000	723	0 m. 760	
		...	...	15	mixed	
—	Paulista Railway Company	367	1 m. 600	528	1 m. 000	Rio Claro.
		...	...	50	0 m. 600	
—	São Paulo Railway (2)	139	1 m. 600	107	1 m. 000	Braganza Company.
—	Argentine Villa Guillermina Railway	426	1 m. 000	164	0 m. 750	
—	Antofagasta and Bolivia Railway	714	0 m. 760	690	1 m. 000	Bolivian Railway, etc.
1.1.1920	Chilian State Railway	...	1 m. 676	...	1 m. 000	Copiapo Railway. Coquimbo Railway. Los Vilos Railway, etc.
		...	...	...	0 m. 600	
	OCEANIA.					
1.1.1922	Australian Commonwealth Railway	1 699	1 m. 435	1 088	1 m. 067	(1 056 m. and 676 m.)
	South Australian Government Railways	1 807	1 m. 600	1 947	1 m. 067	(1 123 m. and 1 210 m.)

(1) Figures supplied by the Companies. — (2) Figures extracted from the official report.

the loading gauge at certain places, reducing the limiting gradient and increasing the radius of curves at others, etc., and whether these would not prove to be a more efficient means of obtaining greater economic improvement of the whole.

This applies specially when a railway system is formed by the amalgamation of smaller systems, a case that frequently occurs at the present time. Each of the railway systems absorbed requires its technical conditions to be examined, and, in order to bring these into harmony, we may proceed by one of three ways, which we will deal with in order of the decreasing magnitude of the work to be carried out.

a) Reconstruction of the absorbed railway system on the same bases as those of the railway system that takes it over.

This change is costly, but it is generally adopted when the railway system that is taken over is of relatively small size. The reconstruction refers to three features : the track gauge, the loading gauge and that of the structural works, and the superstructure of the line. Want of standardization of any one of these conditions would necessitate trans-shipment or involve the exclusive use of the rolling stock which the railway system of smaller dimensions can accept.

We have previously noted, when mentioning the cases of conversion of gauge, the unification of railway systems that has been obtained by widening the narrower gauge. The modification of the loading gauge is carried out similarly. This was the case, for example, on some of the railway systems taken over by the Belgian State Railways.

b) Maintenance of the difference between the conditions existing.

This solution has the advantage that it does not create new financial liabilities, but, on the other hand, it causes the loss of some of the advantages which might have arisen from complete fusion of the two railway systems.

The main disadvantage arises from the maintenance of a difference of gauge which always involves trans-shipment. The number of companies working lines of two different gauges is much greater than is generally imagined. The mileage requiring to be converted is often very large when compared with that of the railway systems with which it is necessary to standardize. Examples are given in Table 41.

Apart from these railways, there are others that work an important system of light railways laid of a different gauge from that of their main lines. The following are a few examples of these :

Table 42. — **Table of railways also working light railway systems.**

Mileage on the	Railway.	Kilometres.	Gauge.	Kilometres.	Gauge.
1.1.1912	Saxony (State) (1)	2 861 10	1 m. 435 1 m.	506 ...	0 m. 750 ...
—	Hungarian (State)	18 308 23	1 m. 435 1 m.	545 14	0 m. 760 0 m. 750
—	Union of South Africa	14 455 (8 982 m.)	1 m. 067	901 (560 m.)	0 m. 600

(1) Extracts from the Official Report.

Finally some large light railway companies have lines of different gauges. As the goods are nearly always transported over a light railway to a main line or *vice versa*, and rarely over a series of light railways, unless one is a branch of another, the disadvantage in having retained different gauges is less in this case. This condition applies particularly to the following companies :

TABLE 43.

Table of light railways having tracks laid of different gauges

RAILWAYS. (Mileage on 1 January 1921.)	Kilometres.	Gauge.	Kilometres.	Gauge.	Kilometres.	Gauge.
National Light Railways Company (Belgium) (1).	3 358	1 m. 000	0 (2)	1 m. 067	30	1 m. 435
East German Railway Co. (3) . .	576	0 m. 750	146	1 m. 000	210	1 m. 435
Vering & Waechter	40	0 m. 750	75	1 m. 000	247	1 m. 435
Pomeranian Provincial Union . .	402	0 m. 750	523	1 m. 000	275	1 m. 435
West German Railway Co. . . .	195	1 m. 000	44	mixed	218	1 m. 435
Munich Local Railway Company .	161	1 m. 435	31	1 m. 000	...	...

(1) Figures extracted from the annual report.
(2) A large railway system of this gauge existed before the war. It has since been reconstructed to metre gauge.
(3) Figures extracted from the *Directory*.

Some Governments that have constructed railway systems in various parts of their territory have in certain cases installed different gauges. Worked as quite distinct railway systems they do not come into the category of the lines that we are investigating here, any more, for example, than do the lines of two different companies having different gauges.

If two railway systems were originally laid of the same gauge, but with different loading gauges, or superstructures, it does not follow that if they are connected later that trans-shipment will be necessary. It may be, however, that the restrictions imposed by sections of different capacity may cause inconvenience and sometimes difficulty in working. The question is more serious from the military point of view, because the large amount of traffic which it may be necessary to move at a particular moment may require the use of all the available rolling stock on certain definite sections, and this is not possible in the case under consideration. This special case must, however, be taken into account, and its importance has been sufficient, for example, to lead to a complete investigation into the possibility of effecting the standardization of the track and loading gauges over the whole of Australia, the execution of which is probable; it is a similar case to that of the reconstruction to metre gauge of the local railway system in Belgium which was destroyed during the war, but which before had a gauge of 1 m. 067 (3′ 6″).

c) CONVERSION OF THE WHOLE OF THE RAILWAY SYSTEM TO THE CONDITIONS OF THE SYSTEM THAT IS TAKEN OVER.

If the system that is taken over is of smaller capacity than the other the adop-

tion of its characteristic features for the whole diminishes the efficiency of the railway system that takes it over and thus involves a total economic loss. This solution has, however, occasionally been adopted. The following are some examples :

Conversion to standard gauge of the fine *Great Western Railway* system, of the broad gauge of 2 m. 134 (7′), before and up to 1892, because it was different from the other railway systems of Great Britain;

Conversion to standard gauge of the *Baden* Railway System (1m. 800 [5′ 10 7/8″]) and the *Dutch* (1 m. 94 [6′ 4 3/8″]) to that of the other European railways;

The *Sceaux line (Paris-Orleans Railway)* altered from 1 m. 75 (5′ 9″) to standard gauge by the law of 1883 to amalgamate it with the general railway system of the Company (¹);

The *Paraguay Central Railway* altered from 1 m. 60 to standard gauge (from 5′ 3″ to 4′ 8 1/2″) in 1912 in order to connect it to the Argentine Railway System and thus give it access to Buenos Ayres.

In Brazil the following lines 1 m. 60 (5′ 3″) have been converted to metre gauge in order that they may form part of more important railway systems :

1905, the *Recife and São Francisco Railway*, of 125 km. (78 miles) (Brazilian Great Western Railway System);

1911, the *Bahia and São Francisco Railway*, 125 km. (Bahia Railway System);

1911, the *Porto Novo Branch* (Brazilian Central Railway), 64 km. (40 miles), (Fluminense System); the *Nictheroy-Cachoeira* line, 73 km. (45 miles) (*Leopoldina Railway* System);

The *Maua Railway*, 18 km. (11 miles); was similarly reduced from 1 m. 676 to 1 m. (from 5′ 6″ to 3′ 3 3/8″) in 1882 (now the *Leopoldina Railway* System);

The *Bahia Central Railway*, 318 km. (197 1/2 miles) of 1 m. 10 gauge reduced to 1 m. (3′ 7 1/4″ to 3′ 3 3/8″) for amalgamation in the Bahia Railway System in 1914;

Chilian State. — The *Serena Coquimbo and Ovalle Railway*, 93 km. (58 miles), constructed as 1 m. 676 gauge (5′ 6″) and reduced to metre gauge in 1910;

The *Tongoy Railway*, 64 km. (40 miles), and those of *Chanaral* and of *Pueblo Hundido* and its branch, 138 km. (86 miles), have been reduced from 1 m. 067 to 1 m. (3′ 6″ to 3′ 3 3/8″) in order to form part of the metre-gauge system of the Chilian State Railway;

In the United States and in Canada numerous broad-gauge tracks have also been reduced to the standard 1 m. 435 gauge (4′ 8 1/2″), 15 000 miles were converted in fact in two days in 1886.

To sum up, of the three methods investigated : adoption of the technical conditions of the main railway system for the whole of the system; maintenance of the existing differences; or adoption of the conditions of the smaller system; the first and the third necessitate conversion and the second may require break of bulk.

CHAPTER IX. — TRANS-SHIPMENT

Having examined the case in which break of load occurs it is well to say a few words about the methods available for reducing the cost and disadvantages of this operation to the minimum.

(¹) It had been constructed on the Arnoux System.

For this purpose we will divide the matter into three groups :

The *first* comprises traffic in which goods have to be unloaded and reloaded for transfer from one railway to another of different gauge;

In the *second* group the goods as well as the wagon body containing them are transferred from a broad gauge to a narrow gauge railway system or *vice versa*;

The *third* group consists of traffic in which goods and the wagons carrying them are transferred from the one to the other railway.

I. — **TRANS-SHIPMENT OF GOODS ONLY.**

This is the most usual method, but the means adopted for carrying it out vary with the size and kind of the goods carried.

The most general case is that of exchange between a light railway and a main line. This is generally only of minor importance; special means are rarely adopted for carrying it out. The trans-shipment is made on the level from wagon to wagon or across a long and narrow platform arranged between the broad-gauge and narrow-gauge tracks; at most the latter is raised in order that the floors of the two vehicles may be at the same height.

Sometimes jib-cranes or gantry-cranes are used particularly when it is a question of trans-shipping bulky or heavy goods such as parts of machinery, timber in the log, etc.

The cost of trans-shipment varies according to the district and the class of goods, as well as the character of the facilities provided for handling by special appliances. The cost per ton is still further reduced when the tonnage trans-shipped is itself large.

In some countries the rates for trans-shipment are fixed by law. This is the case in France and in Austria (1). In British East India an amount was added equivalent to an extra distance of three miles, but these rates did not necessarily represent the exact cost nor did they necessarily over-ride any arrangements which might have been agreed between the companies.

The following are the values given by the *Grundzüge des Kleinbahnwesens* published by the Ministry of Public Works of Prussia (page 192).

TABLE 44.

PRE-WAR PRICES.	Pfennigs per ton.	Centimes per ton.
Tipping coal from standard-gauge wagon at a higher level on to a narrow-gauge wagon below it :		
At Nordling	3.25	3.99
At Hennef (*Bröhlthal Railway*)	8	9.80
Trans-shipment of minerals, lime and coal, by hand labour on the *Bröhlthal Railway*	15	18.45
Trans-shipment of general goods (*Saxon Narrow-gauge Railways*)	15.3 to 17.2	18.82 to 21.15
On the *Bosnabahn* at Bosna Brod	20	24.60
On the *Feldabahn* at Salzungen.	12 to 30	14.76 to 36.90
On the *Kaisersbergerthalbahn*	9.40	11.56

(1) The regulation dated 8 March 1890 fixed this at the uniform figure of 30 centimes per ton. In Austria it was 25 centimes.

Mr. Köpke has calculated the following mean figures at the same date for the various classes of trans-shipment :

TABLE 45.

PRE-WAR PRICES.	Pfennigs per ton.	Centimes per ton.
Goods and packages trans-shipped by hand	50	61.5
Goods in bulk, trans-shipped by hand, per ton (the maximum figure applies to returned empties)	6 to 40	7.3 to 49
Trans-shipment by tipping wagons	30 to 60	37 to 73
(In this case the reduction in cost of trans-shipment is adversely affected by the increase in the cost of transport, the dead weight being much greater.)		
Trans-shipment by means of ponies 25 to 50 pf. per wagon.	2.5 to 10	3 to 12

Finally we must quote the numerous particulars communicated by the various railway companies at the Berne Congress in 1910. (Table 46.)

As will be seen the cost of trans-shipment varied in a number of cases between 25 and 35 centimes per ton.

The examples in the preceding table all relate to exchanges between secondary lines of narrow gauge and main lines of broader gauge.

It sometimes happens that the secondary or light railway may have been constructed of the same gauge as the broad gauge through built as a light railway. This has the disadvantage of costing more per mile than if it had been constructed as a narrow-gauge line, but it has the advantage of allowing the main line vehicles to run on to the secondary line without trans-shipment. It sometimes happens that these latter lines have been constructed under conditions which prevent this. In some cases the track is not strong enough to carry the axle loads of the rolling stock of the main line, in other cases the loading-gauge is too small and necessitates trans-shipment. This is the case for example on the *Brescia-Mantua-Ostiglia Railway*, a secondary line of standard-gauge (1.435 m., or 4′ 8 1/2″) on which the vehicles of the *Italian State Railways* cannot run although of the same gauge. The mean price for trans-shipment at Mantua was at the same period 30 centimes per ton.

All these particulars enable the effect of break of load on cost of transport to be calculated.

Actually the direct cost of trans-shipment is equivalent to an extra distance of *m* miles on the branch line and it increases the rate by a decreasing percentage as the distance run is increased. The cost of transport per ton-mile is less, including capital charges, on the narrow-gauge line, but to this must be added the cost of trans-shipment which is heavier for the first few miles of the distance. The distance beyond which it is preferable to adopt trans-shipment than to construct a branch line of the original gauge can easily be ascertained.

When exchange of goods takes place between two railway systems of equal importance, but of different gauge, and particularly when it is necessary to carry a large quantity of goods in bulk, the rate per ton trans-shipped may be increased on account of the additional

Table 46.

Table of cost of trans-shipment of goods in 1910.

Companies or Administrations.	Goods	Trans-shipment: from a wagon of...gauge	Trans-shipment: to a wagon of...gauge	Cost, in francs, per: 10-ton wagon	Cost, in francs, per: tons, metric.
		m.	m.		
Prussian (State)	general	1.435	0.60, 0.70, 0.75, 0.90, 1.000	2.50 to 3.25	
— —	bricks, etc.	1.435		2.50	...
Saxon (State)	general	1.435	0.750	3.50	...
— —	in sacks	1.435	0.750	2.50	...
Belgium	local	1.000	1.435	...	0.25
—	wood	1.000	1.435	...	0.40 to 0.50
—	trans-shipped by consigner	1.000	1.435	...	Reduction : 20 to 30 °/o
France (Midi)	...	1.000	Narrow.	...	0.20 to 0.50
— (Northern)	oil, sand, minerals, etc.	1.000	—	...	0.20 to 0.30
— —	light or fragile	1.000	—	...	0.30 and over
— (Western)	general	1.000	—	...	0.20 to 0.30
— (Eastern)	—	1.000	—	...	0.30 and over
— (State)	—	1.000	—	...	0.21 mean
— (Anzin)	at Anzin	1.000	—	..	0.20 (5 000 t.)
United States (Boston & Maine) with Hoosak Tunnel and Wilmington	...	1.435	0.914	...	0.50 (10 000 t. per month)
United States (Baltimore & Ohio)	at Fixburg	1.435	Narrow.	...	0.50 to 0.60
Switzerland (State)	...	1.435	—	...	0.45 to 0.50
Rhaetian	at Landquart.	1.000	1.435	...	0.40 (45 000 t. per annum)
Bari-Barletta	wine in barrels	0.750	1.445	...	0.40 (15 000 t. per annum)
— —	liquids in tanks	0.750	1.445	...	0.75
— —	general	0.750	1.445	...	0.35
Prince-Henri	wood, at Echternach	...	...	5.00	...
— —	tiles, etc.	...	...	3.60	...
— —	hewn stone	...	...	4.80	...
— —	fertiliser in sacks	..	...	1.50	...
— —	at Noerdange	...	...	2.25	...
Alsace-Lorraine	...	1.435	1.000	2.50 to 3.00	...
Portuguese Company	...	1.670	Narrow.	2.50	...
— —	wheat at Foz-Fera	1.670	—	1.00	(9 000 t. per annum)

expenditure due to the charges on the greater capital invested in the construction of the line. It is then possible to instal a stage for enabling wagons with tipping sides or hopper wagons to be used.

The cost of trans-shipment carried out under these conditions is lower, and before the war it was from 10 to 15 centimes per ton, to which should be added interest and depreciation on the extra capital invested (1).

II. — TRANS-SHIPMENT OF WAGON BODIES.

Use is frequently made of movable bodies when it is a question of large quantities of goods such as bricks, briquettes or tiles which cannot be trans-shipped by using hopper wagons or other similar means. This system has the disadvantage of increasing the dead weight hauled, but it is cheaper than simple trans-shipment on the level. It is also necessary to increase the expense incurred by the cost of the permanent installation that enables the loaded bodies to be handled either by cranes that lift the body with its contents direct, or by a combination of a pit, or staging, with rails, or by trolleys arranged on the trucks or above them.

a) Trans-shipment of bodies by means of cranes.

This arrangement was in use on the following railways :

The *Anzin Railway* (2). — Exchange of coal with the *French Northern Railway* at Denain, where there was a Renard trench. The movable bodies contained 1.7 tons (3 750 lb.) of coal. Six of these were carried on each 10-ton net wagon. Trans-shipment was effected by a steam crane, the two railway tracks being placed 8 metres (26′) apart. The cost was 8 centimes per ton, pre-war.

French Western Railway (2). — Trans-shipment with the Breton railway system of metre gauge worked by it.

The slates are loaded in special frames each holding 3 tons (6 600 lb.), weighing 0.34 ton (750 lb.) empty and costing 275 fr. each (pre-war). Dimensions : 2 m. × 1 m. 75 × 0 m. 60 (6′ 7″ × 5′ 9″ × 2′). Three of these frames are carried on each 10-ton wagon. Annual traffic : 8 000 tons.

Paris-Orleans Railway. — Similar frames are used for exchange with the lines of the *General Light Railway Company* (*Société générale des chemins de fer économiques*) at Villefranche-d'Allier,

(1) The table given here of the cost of trans-shipment of goods by using a raised track with or without intermediate hopper (in 1910) was as follows :

Railway.	Locality.	Cost per ton, in centimes.	Cost per 10-ton wagon, in francs.	
Prussian State Railway.	...	...	1.50 to 2.00	Ordinary wagon.
			1.00 max.	Narrow wagon with drop bottom.
Western Ry of France.	Chateaubriant.	15	...	Fuel by means of shovels.
		10		Limestone.
Transcaucasian Railway.	Sharopon . .	...	1.25	Manganese 600 000 tons per annum; narrow wagon side tipping.
Great Western Railway.	Chirk . . .	...	...	17 000 tons of stone per year from the Glyn Valley Railway.
Bengal-Nagpur Railway.	Gonda . . .	...	1.25 max.	With intermediate hopper.

(2) Particulars communicated to the Berne Congress in 1910.

where 10 000 tons of fuel are trans-shipped annually.

b) **Container system**.

For some time past a system has been in use in the United States which differs slightly from that of movable bodies. It is only used to make trans-shipment between lorries and railway wagons easier, but it can be used under the same conditions for trans-shipment between wagons of different gauges. Actually it is a system that has been in use in Europe for many years and reappears here under a new name. It is used in particular for the carriage of luggage between Paris and London by the *French Northern Railway* and the *South Eastern & Chatham* line and the Channel steamers, the *containers* in this case are of wood.

In the United States there are arranged side-by-side on a flat topped low-sided wagon a series of large metal boxes the double doors of which are kept shut by the sides of the flat wagon. The *containers* may be partially filled and they have the further advantage that they cannot be opened during the journey, which reduces the loss by theft and damage.

The *River & Rail Transportation Co.* of St. Louis were constructors of the *Trinity Freight Unit.* For this, *containers* are used of 2 1/2 or 10 tons capacity. The truck carries, according to circumstances, 20 *containers* of 2 1/2 tons or 5 of 10 tons. The cost of the apparatus enabling the containers to be secured to the truck is estimated at $250 and the five 10-ton *containers* cost $1 000 (1). The United States Government Railway Administration estimated the saving resulting from their use at 300 to 400 %, without taking into account the acceleration in the work of trans-shipment. Deduction should be made from this saving, however, on account of the cost of the cranes necessary for these trans-shipments.

The *New York Central Railway* uses *containers* for mail service (1) arranged on standard wagons 60′ long. These containers, nine in number are 9′ × 6′ × 7′ high inside and have each a capacity of 6 000 lb.

The *Merchants Despatch Transportation Co.* uses wagons 46′ long carrying three *containers* each 15′ long. It uses these to reduce the amount of compensation to be paid on account of theft and damage which in 1920 were 300 % greater than in 1914.

The *South African Railways* at Durban use a similar arrangement made by the *Canadian Car & Foundry Co.* They use five *containers* of 10 to 12 tons each per flat low-sided wagon.

III. — TRANSPORT OF THE LOAD AND OF THE WAGON CONTAINING IT OVER TWO LINES OF DIFFERENT GAUGE.

This method, which avoids trans-shipment as generally understood, can be effected by one of the three following methods which apply to the rolling stock, or to the track, or to both :

A) by dealing with the rolling stock alone trans-ship vehicles can be used running on a track of one gauge and carrying the rolling stock of the other gauge;

B) by dealing with the track alone, this is equipped with additional lines of rail, the mixed section comprising both gauges and enabling both kinds of rolling stock to be run over it;

C) dealing with both track and rolling

(1) *Railway Age Gazette*, 1920, II, p. 515.

(1) *Railway Age Gazette*, 1921, I, p. 314.

stock, by the use of vehicles with bogies or so-called « extensible » axles or interchangeable axles and of a section of track or a special installation that enables the rolling stock to be converted rapidly from one gauge to the other.

The first method has the disadvantage of increasing the dead load hauled and it requires the use of auxiliary rolling stock. The second requires a considerably greater outlay of capital on the original equipment. The third involves slightly increased cost of installation only and, if it were generally adopted, it would without doubt be the best of the three methods; it is however, in the experimental stage as yet.

We will deal with these methods in order and briefly.

A) THE USE OF TRANSFER VEHICLES.

The principle of the system consists in transporting the loaded vehicles on trans-ship trucks, or less frequently on trans-ship wagons running on the track of the other gauge. This enables the branch line not only to eliminate the cost of trans-shipment but also to reduce its total number of wagons.

If, notwithstanding this, it can charge the trans-shipment rate, it will be able to distribute it over the total mileage run by trans-ship vehicles. The charge collected by the main railway for rolling stock must also be taken into account, but in many cases the time that this rolling stock stands idle would be reduced by the use of trans-ship vehicles; frequently also no charge is made for demurrage.

We will now consider briefly the conditions which should be met by a line of narrower gauge in order to be able to use trans-shipped vehicles, because it would not only be necessary that its loading-gauge should allow the passage of the broad-gauge rolling stock over the narrow-gauge track, but also that the track should be able to carry it.

The road bed has generally a sufficient width and the loading-gauge allows the passage the more easily for the reason that the lower part, which is often the narrower, need not be considered, because of the extra height to which the broad-gauge wagons are raised when trans-shipped.

Under-bridges are usually of adequate dimensions. At the most they only require to be widened by corbelling for the footways. Over-bridges seldom exist on lines of this class; they must be of a minimum width of 4 m. 50 (14′ 9″) and height of 4 m. 70 to 4 m. 80 (15′ 5″ to 15′ 9″).

The bridges and track are generally strong enough, because normal-gauge wagons are carried on bogies or trans-ship trucks with four axles, of which the axle-load is less than that on the driving axles of the narrow-gauge locomotives. Nevertheless, it would be necessary to make provision, at exchange stations, for the space necessary for trans-shipment which varies according to the system adopted.

Finally it would appear that, when trans-ship vehicles are used on a small scale they may render great services, because they enable works and other concerns to be put into direct communication with the normal-gauge track which would not otherwise be the case.

When they are used extensively, it is necessary to consider whether it would not be well to alter the section of line in question to a three or four rail track or even to convert it to the broader gauge. We should, however, say that this may not be necessary and that each case must be considered on its merits.

The use of transfer vehicles is much greater than is generally supposed to be the case; thus we may mention a number of examples grouping these into three classes [1]:

a) Transfer bogies;
b) Transfer wagons;
c) Transfer vehicles for boxes on small wheels.

a) Transfer bogies

The cost of a pair of Langbein bogies — those most in use — was (pre-war) 3 500 fr. The cost of a sunk pit having capacity for ten bogies may be estimated at 2 500 fr. Then calling

p, the number of pairs of bogies;
T, the annual tonnage;
a, the number of pits;
f, the cost in francs of labour of transshipment of one ton of goods.

Then the total cost of installation with Langbein bogies per annum is :

$$f + \frac{(3\,500\,p + 2\,500\,a)\,(0.15 + 0.02)}{T}$$
$$= f + \frac{85\,(7p + 5a)}{T}$$

taking interest and depreciation at 15 % and the annual cost of maintenance at 2 % of the cost of the special installation.

In some countries, particularly in Austria, the number of bogies has been limited to one set per train; in others such as Würtemberg it has been made a rule that they must be fitted with brakes. From the point of view of safety it does not appear that these precautions are necessary. Elsewhere, and particularly at Forst, trains are made up consisting entirely of these bogies connected to each other and to the locomotive by rigid draw-rods and run quite satisfactorily. The maximum speed of 15 km. (9.4 miles) per hour should not be exceeded.

The use of transfer bogies has been considerably increased during the last few years in Germany and in Austria and has even reached a mean figure of 62 wagons per day on the line that carries most traffic and distributes the wagons of the main railway line picked up at the station and delivered to the numerous works of the same town.

The following are some particulars re-

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[1] *Table of railways using transfer vehicles.*

Aarau Schöftland	Bogies.
Barsi Light Railway	Wagons.
Bavarian State Railway	Bogies.
Belgian Local Railways	Bogies.
Berne-Soleure Railway	Wagons.
Bern-Worb Railway	Wagons.
Bern-Zollikofen	Wagons.
Bienne-Anet	Wagons.
Bienne-Macolin	Wagons.
Brienz-Meiringen	Wagons.
Brunigbahn	Wagons.
Deux-Sèvres	Bogies.
Geneva Electric Tramways	Bogies. — Wagons.
Kolding Egtveld	Boxes on small wheels.
Langenthal-Jura	Wagons.
Leek & Manifold Light Railway	Wagons.
Montreux-Bernese Oberland	Wagons.
Munich Local Railway	Bogies.
Norwegian State Railway	Bogies.
Paris-Lyons-Mediterranean	Bogies.
Prince-Henry Railway	Bogies.
Prussian State Railway	Bogies. — Wagons.
Saignelégier-La-Chaux-de-Fonds	Wagons.
Saxon State Railway	Wagons.
Schaffhausen Tramways	Wagons.
Worblentalbahn	Wagons.
Würtemberg State Railway	Bogies.
Wynenthalbahn	Bogies.

lating to the use of the Langbein, or similar bogies, on a number of railways :

Germany. — Prussian State. — On 53 trans-ship installations between lines of different gauges in existence in 1910 there were in use :

Langbein bogies on eight of these;

Transfer wagons on two others;

Arrangements on the level or by staging elsewhere.

Bavarian State Railway. — This administration has used the Langbein bogies since 1887.

Munich Local Railway. — This company has the most complete installation of Langbein bogies. It is located in the town of Forst and it runs from the standard gauge railway station into the town of Forst over a metre-gauge track to which 77 works are connected. The annual traffic carried by Langbein bogies is 230 000 tons, of which 190 000 tons is coal arriving by the main line railway. This requires an exchange of 60 to 80 loaded wagons and as many empties per day. The equipment of the line comprises 98 bogies and 3 pits (at Forst station) each for ten pairs of bogies.

Würtemberg State Railway — This administration generally uses these bogies.

France. — State Railway System. — The Deux-Sèvres Tramways. — Since 1902 this Company has used 7 pairs of bogies on the Saint-Maixent line over the 3.5 km. (2.2 miles) connecting the Mardre distillery with the Melle station of the *French State Railway System*. The prewar traffic was 35 standard-gauge wagons per day and has since been more than doubled. These wagons carry from 25 to 28 tons gross of alcohol including the weight of the tank.

The bogies are generally arranged as special trains, but occasionally are attached to the rear of passenger trains.

The tires of the standard-gauge wheels are carried at a height of 0 m. 38 (1′ 3″) above the level of the rails.

Paris - Lyons - Mediterranean Railway. — Bogies of the same class are used in Haute-Savoie from Le Fayet to the Chedde works. This is connected to the metre-gauge track running from Le Fayet to Chamonix by a private siding of standard-gauge. It was arranged thus in order to receive and load in the works standard-gauge wagons coming from or destined for beyond Le Fayet where the narrow gauge begins. They differ from the preceding in two characteristic features : the wagons of standard-gauge are not raised so high, the tread of the wheels being only 0 m. 23 (9″) above the level of the rail and the coupling in this distance is not made between the bogies, but directly between the loaded standard-gauge wagons. There is an intermediate coupling-vehicle between the first of these latter and the locomotive, or the narrow-gauge rolling stock which precedes it; this intermediate wagon is fitted with coupling and buffing apparatus corresponding to both the gauges.

Belgium. — National Light Railways Company. — This Company has made use of a few bogies, but has not gone further. On the other hand when it is a question of sufficiently large traffic between its railway system and the standard-gauge railway system it uses a four-rail track.

Luxembourg. — Prince-Henry Railway. — Exchange between the standard-gauge tracks and a narrow-gauge track at Grundhof is made exclusively by means of these

bogies the line not being equipped with other rolling stock. The tonnage which consists of the output of and the supplies to the Dillingen quarries, amounts to 15 000 tons per annum. The equipment consists of six pairs of bogies and two pits. The cost of installation (including interest and depreciation) amounted to 27 centimes per ton (pre-war).

NORWAY. — In Christiania the bogies are used to avoid trans-shipment of certain classes of goods only, between the Norwegian Western Railway System of normal gauge 1 m. 435 (or 4′ 8 1/2″) and the Eastern Railway System 1 m. 067 (or 3′ 6″) gauge and *vice versa*. The equipment comprises five pairs of bogies on the narrow-gauge line and three on the normal-gauge line.

SWITZERLAND. — GENEVA ELECTRIC TRAMWAY COMPANY. — This Company arranged for the use of Langbein bogies at the time of the Geneva Exhibition in order to avoid the trans-shipment of a quantity of goods arriving at Cornavin station by normal-gauge track. In a very short period it carried in this way 240 wagons for the opening and 290 at the closing of the Exhibition, and greater use was afterwards made of the bogies.

In 1909 as the result of the construction of twelve sidings to works (gas works, flour mills, tile works, machinery works, etc.), the number was increased to 18 pairs which carried 7 500 wagons, or more than 90 000 tons during the year. The mean distance run is from 3 to 4 km. (2 to 2 1/2 miles) with the exception of a hundred wagons of fuel and wine carried 18 km. (11 miles).

The system worked without trouble, so well in fact that the Company adopted the principle. Following on this it tried trans-ship wagons instead of the Langbein bogies and finished by abandoning these in favour of wagons. For this reason this application is of great interest.

b) Transfer wagons.

Transfer wagons are less used because their tare is from 20 % to 25 % greater than that of the bogies. On the other hand they have the advantage of being able to carry, equally well, stock with two, three, or four axles, whereas the bogies can only carry four-wheel wagons.

GERMANY. — The PRUSSIAN STATE RAILWAY used transfer wagons in 1910 in two of its exchange stations only.

The SAXON STATE RAILWAY made more use of them. Their wagons are flat-topped, low, bogie wagons with two or three axles to each bogie and fitted with rails of standard gauge arranged in a longitudinal direction. These wagons serve for exchange between the railway systems having tracks of standard 4′ 8 1/2″ gauge and the 0 m. 75 (2′ 5 1/2″) gauge of this administration.

ENGLAND. — The LEEK & MANIFOLD LIGHT RAILWAY, a small railway 0 m. 76 (2′ 6″) gauge 13 km. (8.1 miles) long uses almost exclusively transfer wagons constructed by Cravens, on the Calthrop system, for the whole of its wagons. The wagons carry on each side a track 18″ wide with a groove that makes it equivalent to the rail for vehicles of normal gauge. These are carried at a height of ten inches above the narrow-gauge rail level.

The BARSI LIGHT RAILWAY uses similar transfer vehicles.

SWITZERLAND. — In 1910 there were in Switzerland five railways and one private

(works) railway having in all six transfer wagons and thirty-six pairs of bogies. The rate at which the use of these vehicles has since grown is shown in the table.

TABLE 47.

Table showing the number of transfer vehicles used in Switzerland from 1912 to 1917.

YEAR.	Number of railways.	Number of transfer wagons.	Number of pairs of Langbein bogies.	Length of line worked, in kilometres.	Axle-kilometres.
1912	7	27	36	191	576 000
1913	9	40	36	219	667 000
1914	10	57	36	230	689 000
1915	11	62	36	255	717 000
1916	13	72	36	311	1 067 000
1917	13	86	36	335	1 278 000

It will be seen that the use of pairs of bogies [1] has not increased and that transfer wagons are preferred to them and used even on gradients amounting to as much as 1 in 15 1/2. The maximum speed permitted is 25 km. (15.5 miles) per hour except for the recent spring-suspended arrangements for which speeds of 45 km. (27.5 miles) per hour are permitted.

Table 48 gives data of the use of transfer wagons in Switzerland [2] on the 1st January 1921.

MONTREUX-BERNESE-OBERLAND RAILWAY. — The transfer wagons [3] of this company belong to the metre-gauge track used for electric traction from *Zweisimmen* to *Lenk*. These are flat-topped vehicles with dropped frames and with bogies. They are fitted on each side

TABLE 48.

	Transfer wagons with four axles.
Railways.	
Brunig Railway	17
Aarau Schöftland	(18 Langbein bogies).
Berne-Worb	4
Berne-Zollikofen	15
Bienne-Macolin	2
Bienne-Anet	5
Langenthal-Jura	2
Langenthal-Melchnau	3
Soleure-Niederhipp.	2
Montreux-Bernese-Oberland	3
Saignelégier-La-Chaux-de-Fonds	3
Soleure-Berne	6
Worblenthalbahn	10
Wynenthalbahn	(20 Langbein bogies).
Tramways.	
Geneva Electric Tramways	27
Schaffhausen Tramways	7

(1) Particulars supplied by the Swiss Ministry of Posts and Railways.
(2) According to the Official Statistics of Railways.
(3) Called « trucs » (bogies) by this railway.

with rails of standard gauge between the inner faces and capable of carrying a standard-gauge vehicle of a maximum weight of 30 tons. Their tare weight is 6.9 tons (15 200 lb.).

In 1916 this railway had in service three of these vehicles fitted with ball-bearings and loose-running wheels on the system devised by the *Fabrique Suisse de Schlieren* and by the firm of *Schmid-Roost.* On trial they attained a speed of 50 km. (31.1 miles) per hour, and they are fitted with a Hardy automatic vacuum brake giving pressures on the brake shoes of 5.4 tons, 10.8 tons, and 16.8 tons (11 900, 23 800 and 37 000 lb.). The resistance to traction on the straight is 2 kgr. 3 per metric ton (5.14 lb. per English ton) (it is 5 kgr. 3 per metric ton [11.9 lb. per English ton] with ordinary plain bearings). (Fig. 11.)

Brienz-Meiringen Railway. — The transfer wagons of this line of metre gauge, which was opened for working on the 23 August 1916, closely resemble those just described. They were made by the *Ateliers des Chemins de fer Fédéraux* (Swiss Federal Railway Works), the *Fabrique suisse de wagons Schlieren* (of Zurich) and the *Société Industrielle suisse de Neuhausen* (of Schaffhausen); they have a tare weight of 8.5 tons and a carrying capacity of 30 tons. They are fitted with a Westinghouse brake, and are piped for steam heating, enabling them to be inserted into any train.

The tread of the wheels of the standard-gauge wagon is carried at 0 m. 525 (1′ 8 5/8″) above the level of the rail. A transfer wagon can carry wagons of which the maximum distance between axles amounts to 7 m. 90 (25′ 11″). If this distance is exceeded, the wagon is loaded on two transfer wagons the wheels being fastened at one end only of the transported wagon. The following are the main dimensions of the transfer wagons in use on this railway :

Length over buffers	10 m. 00 (32′ 10″)
Length of underframe . . .	9 m. 28 (30′ 5″)
Width of underframe. . . .	1 m. 44 (4′ 9″)
Width over side carrying rails.	1 m. 68 (5′ 7″)
Height of side carrying rails. .	0 m. 525 (1′ 8 5/8″)
Height of centre of buffer . .	0 m. 65 (2′ 1/2″)
Diameter of wheels	0 m. 68 (2′ 2 3/4″)
Wheel base of bogies. . . .	1 m. 20 (3′ 11″)
Centre to centre of bogies . .	5 m. 50 (18′ 1/2″)
Over-all wheel base	6 m. 70 (22′)

Geneva Electric Tramway Company. — This Company has for a long time been using transfer vehicles for effecting direct working without trans-shipment, between Geneva-Cornavin, the exchange station, and the large railway systems and the works and warehouses of the area served by it.

It commenced by using Langbein bogies, which it abandoned in favour of transfer wagons analogous to those of other Swiss railway systems.

The Geneva Tramway Company uses them on distances varying from 3 to 22 km. (2 to 13.6 miles); the annual traffic exceeds 8 000 wagons, and provides 70 % of the total receipts from goods traffic.

The rolling resistance of these wagons is small and the consumption of current required for hauling them is not abnormal. Trials have been made with trains consisting of a 19-ton tractor, of two transfer wagons weighing together 9 tons empty and 39 tons loaded, and of two ordinary wagons each weighing 8 tons; the return journey being made empty the train weighed only 44 tons instead of 74. Under these conditions the mean consumption for the out-and-home trip, which required to be con-

Fig. 11. — Trans-ship wagon with ball bearings, Montreux railway (Bernese-Oberland).

Fig. 11a.

Fig. 11b.

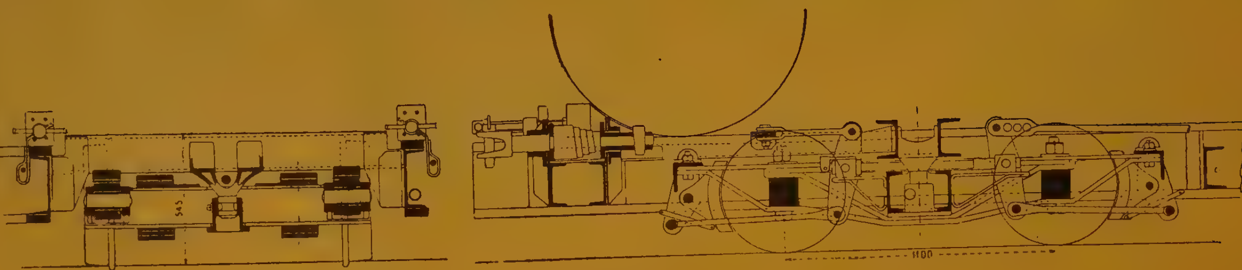


Fig. 11c.

sidered, was 3.32 kw.-h. per tr.-km. (5.34 kw.-h. per train-mile) or 56 w.-h. per ton-kilometre (91.56 w.-h. per English ton-mile).

c) Transfer wagons for special trucks fitted with small wheels.

The two systems which we have just examined enable a vehicle which runs on a line of one gauge to be transported over a track of different gauge by means of a transfer vehicle. The system with which we are now going to deal differs radically in so far as it requires the use of transfer wagons on each of the gauges in question. The trans-shipped vehicle is then a mere box fitted with small wheels.

Denmark. — Trans-shipment between the Danish State Railway and the narrow-gauge Railway from Kölding to Egtveld.

Flat-topped wagons are used each fitted with two lines of rails in a longitudinal direction. The movable boxes are carried on wheels 0 m. 16 (6 1/4″) diameter which can run on the rails. The trans-shipment is made by backing the standard-gauge and narrow-gauge wagons together and laying the ends of flying rails across from the one to the other. The narrow-gauge track should be raised above the height of the standard-gauge track in order that the floors of the wagons may be at the same height; the normal heights of the floors are : 0 m. 83 (2′ 9″) and 1 m. 23 (4′ 7/16″).

Twenty-four narrow-gauge wagons and six standard-gauge wagons have been fitted with these auxiliary rails. The Company has 60 boxes six of which are covered and used for carrying perishable articles of food and also for the sugar traffic to the port of Kölding.

B) TRACKS WITH THREE OR FOUR LINES OF RAIL.

Strictly speaking this is not trans-shipment properly so called, because nothing is actually trans-shipped. But as the method has for its object that of allowing vehicles of one gauge to run over the track that has been laid for another gauge and of avoiding trans-shipment, we shall examine its features on this basis.

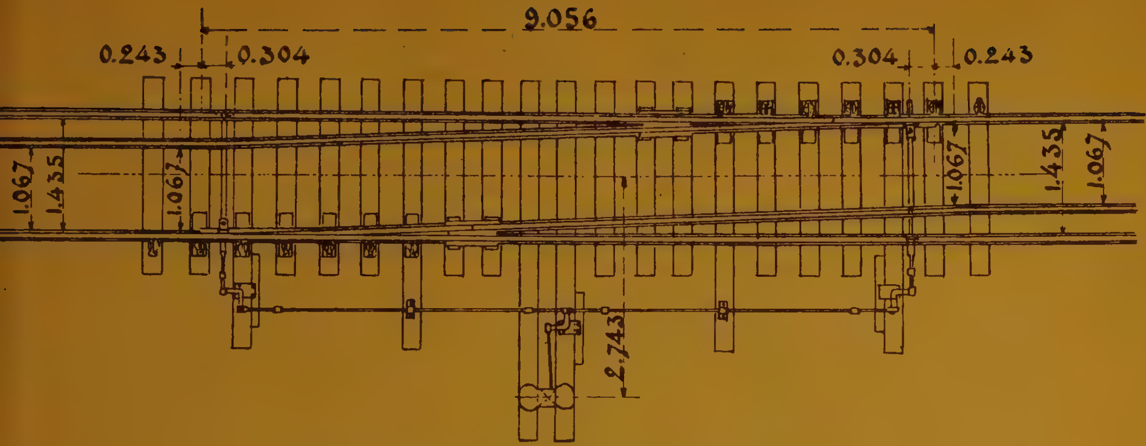
The mixed-gauge tracks can be divided into three classes :

a) *The first class* allows wagons of one gauge of track to run over the line of a different gauge up to a terminal point or the point of origin of relatively heavy traffic.

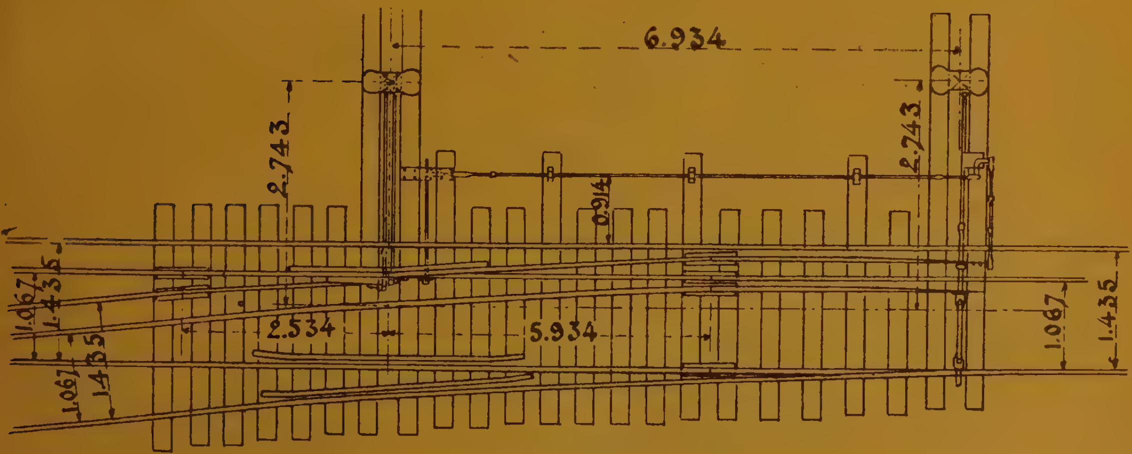
These sections are generally short; the cost of trans-shipment per ton spread over the distance run on a line of which the track has several rails, diminishes with its length. As soon as the length is great, the total cost of freight can more easily carry the expense which would be incurred in the trans-shipment at the exchange station. But tracks with three or four rails cost a great deal; also the use of the third or the fourth rail should be avoided when the share of the cost of trans-shipment over this longer distance is sufficiently large.

b) *The second class* allows wagons of one line built to a particular gauge to connect up with another line of the same gauge by using a length of track laid to a different gauge the length of which varies according to the circumstances of the case. Generally this happens where for local reasons two lines of different gauge are laid close to one another.

c) *The third class* of lines, with three lines of rail, is that used on temporary railways. The most general application is made during the period of change over of the gauge of a railway. A third rail



Throw-over for common rail without crossing (Frogless switch).



Mixed-gauge points.

Fig. 12. — Prince Edward Island Railway. — Mixed-gauge tracks.

is then laid to the new gauge before removing one of the old rails and a section is worked temporarily with mixed gauge. We have quoted examples in speaking of the English *Great Western Railway*, of the first *South African Railways*, of the *Prince Edward Island Railway* System, etc.

The following are the particulars of the railways of each of the three classes :

a) **Sections of line with three or four rails.**

GERMANY. — WEST GERMAN RAILWAY. — 44 km. (27 miles).

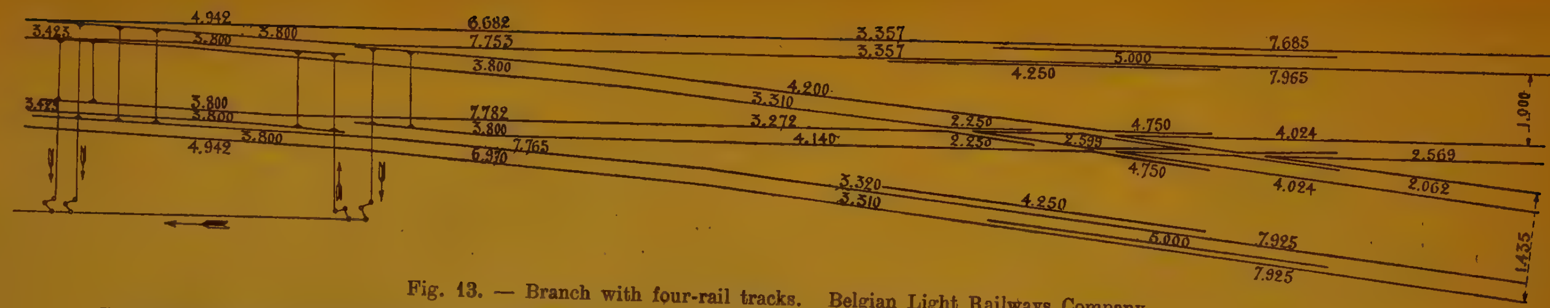
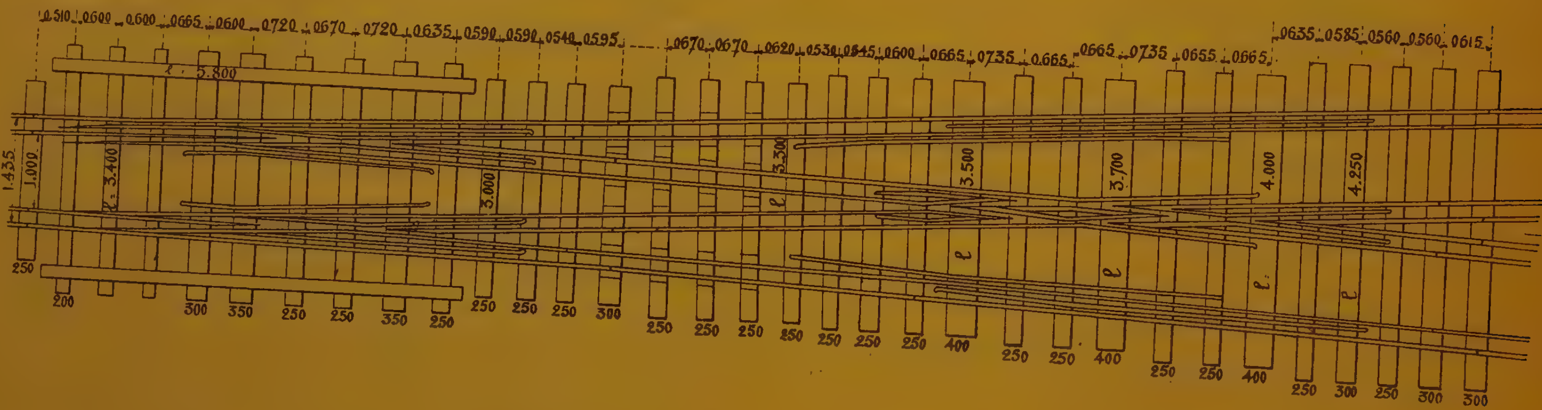


Fig. 13. — Branch with four-rail tracks. Belgian Light Railways Company.

Total length over points and crossings : 35 m. 255 (115′ 8″). — Length of point-tongues : 3 m. 800 (12′ 5 5/8″). — Weight of rails : 30 kgr. per m. (60.48 lb. per yard. Gaps in crossing : 45 and 35 mm. (1 25/32″ and 1 3/8″).



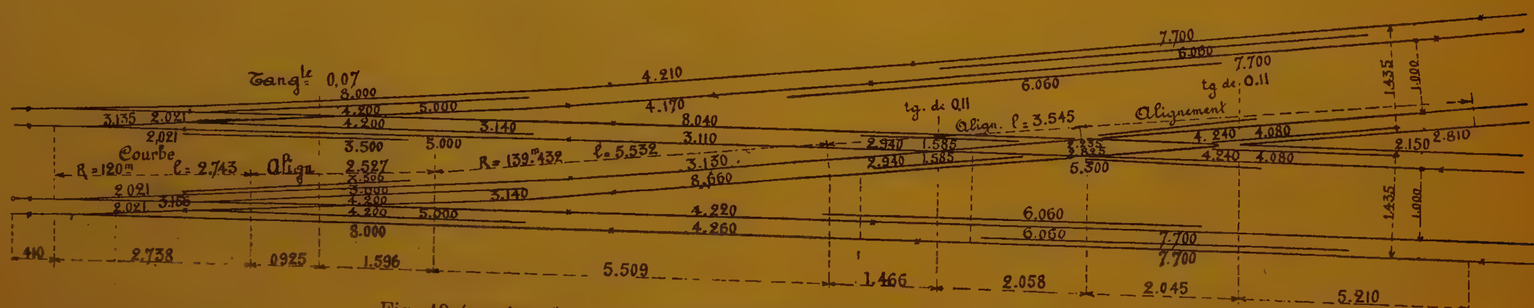


Fig. 13 (*continued*). — Branch with four-rail tracks. French Northern Railway.

Total length over points and crossings : 19 m. 957 (65′ 5 11/16″). — Length of point-tongues : 2 m. 021 (6′ 7 9/16″). — Weight of rails : 30 kgr. per m. (60.48 lb. per yard). — Minimum curve radius : 139 m. (6.95 chains). — The outer gaps in the crossing have been reduced, which has been rendered possible by reducing the gauges respectively from 1 m. 445 to 1 m. 440 (4′ 8 7/8″ to 4′ 8 11/16″) and from 1 m. 000 to 0 m. 995 (3′ 3 3/8″ to 3′ 3 11/64″).

Meanings of French terms : Alignment = Straight. — Courbe = Curve. — Tang^te = Tangent.

Belgium. — National Light Railways Company. — This Company, of which the greater part of the railway system is metre gauge, has however some lines of standard-gauge. Moreover, to connect some points on the metre-gauge line with stations of standard-gauge, and to avoid the trans-shipment of heavy traffic, it has fitted some sections with three or four lines of rail (1) (figs. 14 and 15).

France. — Alsace-Lorraine Railway. — The section from Colmar (station) to the port 5.670 km. (3.523 miles), is laid with three rails. There are also 38.020 km. (23.624 miles) of four-rail track.

French Southern Railway. — 150 km. (93 miles).

French Northern Railway. — The only sections with four rails are the following (fig. 13):

Saint-Just to Plainval (towards Montdidier)	2 km. 400	(1.490 miles)
Vicinity of Saint-Roch	0 km. 692	(0.43 mile)
Vicinity of Frévent	0 km. 393	(0.245 mile)
Line from Noyelle to Saint-Valéry	5 km. 585	(3.470 miles)
	9 km. 070	(5.635 miles)

Intermediate wagons are only used on the last-section; they run on the narrow-gauge track.

Paris-Lyons-Mediterranean System. — Section of 4 km. (2.48 miles) from Bourbon-Lancy (station) to the town, belonging to the *Departmental Railways*. Mixed-gauge track of standard and metre-gauges with four lines of rail. In 1907, there were 500 standard-gauge wagons running over this of which 235 were cattle wagons.

There is also a similar section 4.244 km. (2.636 miles) long between Vichy and Cusset; intermediate wagons are used on both these sections.

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(1) *Sections of line common to the Belgian Light Railways Company and to the Belgian State Railways laid with three or four rails.*

Section of line	With four rails.		With three rails.	
	Main.	Supplementary.	Main.	Supplementary.
	Metres.	Metres.	Metres.	Metres.
Moll (Donck) to Moll (station)	4 723	1 159	...	...
Branch to Brussels (abattoirs)	425	226	...	...
Branch to Cureghem (abattoirs)	993	...	...	...
Common section to Heyst	534	..	..	...
Espierres to Warcoing	3 500	...	...	...
Common section to Baudour	4 424	766	...	...
Neufvilles (station) to the quarries	5 902	1 870	...	...
Chimay to Forges	4 688	1 489	...	...
Ouffet-Comblain-au-Pont	13 253	3 429	...	...
Mons (Crotteux) to Jemeppe-sur-Meuse	7 107	2 095	...	...
Various connections	...	...	461	2 870
Sections common to the tramway companies :				
With the Liége tramways	963	...	...	...
With the Brussels tramways	...	...	4 201	...
Totals	46 512	11 034	4 662	2 870
	57 546		7 532	

Finally the Departmental Railway systems use and are laying three or four lines of rail on the road-beds of the Paris-Lyons-Mediterranean system :

On the line from *Givors to La Voulte* : 2 158 m. and 899 m. (2 360 yards and 973 yards);

On the line from *Cravant to Les-Laumes* : 621 m. (679 yards).

Fig. 14. — Branch with four- rail tracks. Belgian Light Railways Company.

PARIS-ORLEANS RAILWAY. — The total length of branch lines laid with three rails is 1 537 m. (1 680 yards) and with four rails 1 127 m. (1 232 yards).

Moreover, the line from Argent to Gien is laid with four rails from Argent station for a length of 380 m. (415 yards) of main track forming a common trunk line, followed by a section of 820 m. (897 yards) of three-rail line towards Gien (included in the branch lines above).

SOUTH AFRICA. — During the period of conversion of the normal-gauge leaving Cape Town into the 3′ 6″ gauge which had been adopted for the general railway system, a third rail was used over a great portion of the 4′ 8 1/2″ lines (we shall give details when dealing with the standardization of railway systems).

b) **Lines with three or four rails.**

The length of lines of the second class does not follow the same rules. It is in fact a question of a connecting line which, owing to local conditions, follows the same route as a portion of the existing

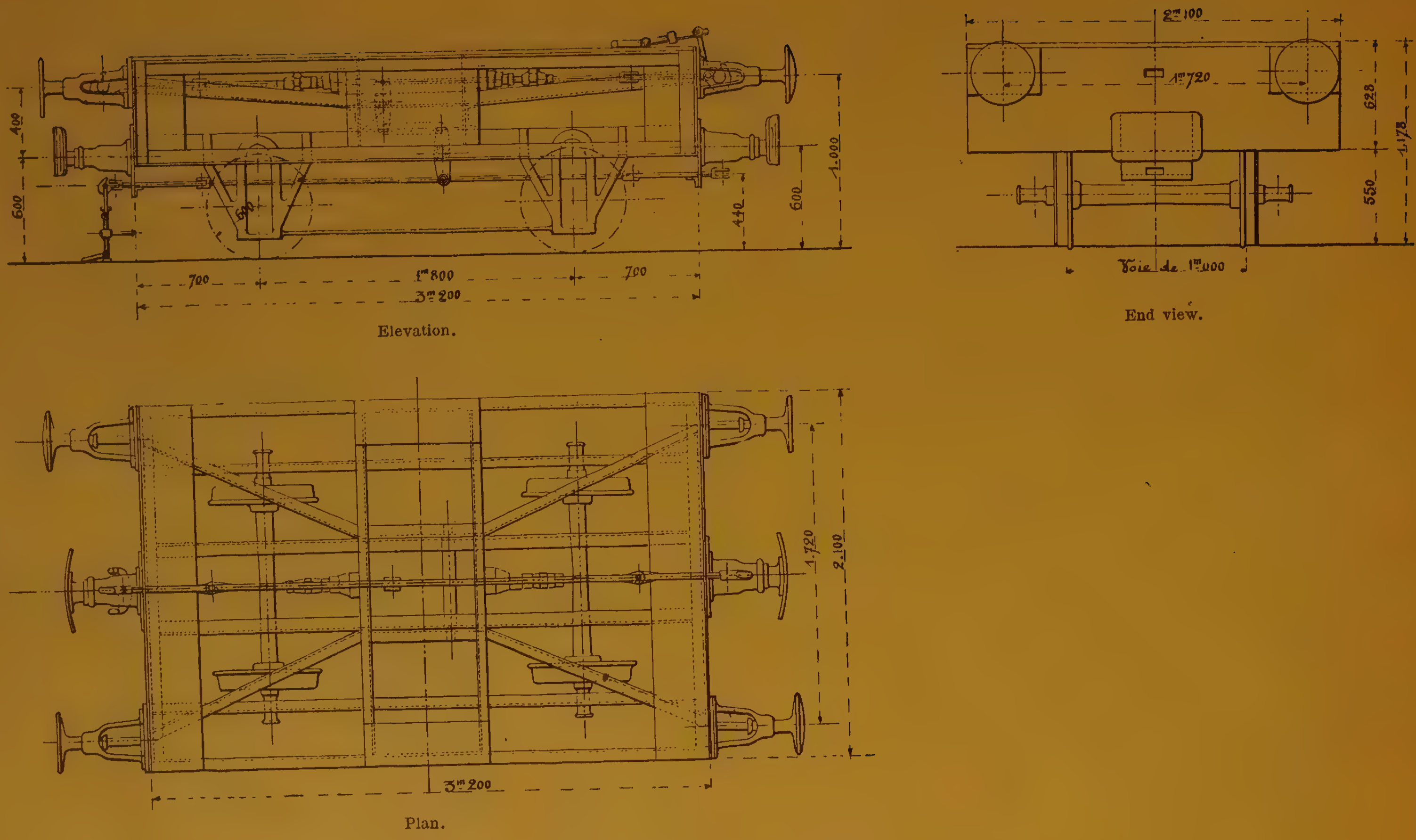

Fig. 15. — Intermediate wagon. Belgian Light Railways Company.

Explanation of French terms : Voie de 1 m. 000 = 3′ 3 3/8″ gauge.

line laid of a different gauge. Questions of tonnage and interchangeability of traffic between the lines that are to be connected are alone of importance; moreover, lines of mixed gauge may be short or may be very long. We will quote some examples grouping them by Continents.

EUROPE. — ENGLAND. — The most complete example of mixed gauge tracks is that of the old *Great Western Railway* at the time of « the battle of the gauges » during which the third rail was laid over very long sections in order to avoid transshipments.

In FRANCE an interesting example is that of the standard-gauge section of the *French Northern Railway* system between Noyelles and Saint-Valéry. Two lines of metre gauge of the *General Light Railway Company* (*Société générale de chemins de fer économiques*) join the main line respectively at Noyelles and at Saint-Valéry; a third rail was laid in 1887 between these two places in order to ensure the connexion of the two narrow-gauge lines.

AMERICA. — THE ARGENTINE REPUBLIC. — The lines of the *Port of Buenos-Ayres* are almost all laid to the two gauges of 1 m. and 1 m. 676 (5′ 6″).

BRAZIL. — CENTRAL BRAZILIAN RAILWAY (State Railway System). — The *Central Railway* of 1 m. 60 (5′ 3″) leaving Rio de Janeiro passes through Parahyba do Sul (km. 187), Entrerios (km. 198), Lafayette (km. 462) to finish a temporary terminus at Pirapora (km. 1006). Beyond Miguel Burnier (km. 498) it is metre gauge.

The line known as the *Auxiliary line*, of metre gauge, runs from Rio to Parahyba do Sul (km. 168) by Estiva. A third rail was consequently laid over the 3 kilometres (1.86 miles) common to both from Rio as well as over the 11 kilometres (7 miles) from Parahyba do Sul to Entrerios, an important centre. There is a broad-gauge branch line from this point to Porto Novo (km. 261) whence the continuation is by the metre-gauge line of the Leopoldina Company. The third rail has since been extended to Entrerios, its length from Parahyba do Sul being 63 km. (39 miles). (See fig. 20.)

There was another section of mixed-gauge on the same railway from Lafayette (km. 462), to Miguel Burnier (km. 498) and thence to the sixth kilometre of the Ouro Preto mining branch line (km. 39) of the branch line (see fig. 21). The total length of mixed-gauge lines to 1 January 1911 was : 118 km. (73.32 miles).

CANADA. — For a long time Canada and the United States had lines of different gauges. When the bridge was constructed at Niagara this connected the *Erie Railroad* with the *Great Western Railway* of Canada, which was of broad-gauge, and a third rail was laid on the bridge as well as over 140 km. (87 miles) of the latter railway.

It is only during the last few years that the unification of gauge throughout the Dominion has been completed, and this has been done since the taking over of the *Prince Edward Island Railway* system comprising 446 km. (277 miles), which had become the *Insular Railway* of the Canadian National Railways, of which the gauge was 3′ 6″.

But, as the financial conditions were not good, the change over was made by stages and some sections were temporarily laid with three lines of rail to cover the two gauges of 4′ 8 1/2″ and 3′ 6″. The beginning was made on the 47 miles of main line from Charlottetown to Sum-

merside and on the branch from Emerald Junction to Borden (13 miles) where trans-shipment was avoided by the Port Borden to Cape Tormentine *Train-ferry*. This third rail had to be extended beyond Summerside to Tingish.

The track was so laid that the centre of the standard gauge track came in the centre of the sleepers. It was therefore necessary to move the inside rail corresponding to the narrow-gauge track inwards by half the difference between the two gauges. Usually the third rail was laid so that the North side of the track was wide but it was not possible to maintain this rule absolutely in consequence of the direction in which the points were taken. The difficulty was surmounted by using sometimes one rail and sometimes the other as the common rail, the narrow gauge then crossing from side to side of the standard gauge (fig. 12).

CHILI. — The metre-gauge railway from *Coquimbo* to *Serena* (km. 14) and *Rivadavia* (km. 94) has a mixed-gauge section between Serana Coquimbo in order to allow vehicles of the 1 m. 676 (5′ 6″) gauge of the *Ovalle-Coquimbo Railway* (98 km. [61 miles]) to run on to Serena.

In 1910, after it had been purchased by the State, the track of this last section was reduced to metre gauge.

ASIA. — BRITISH INDIA. — In the Indies there are several sections of three-line tracks but these are less numerous than would have been at first thought. They are as follows [1] :

TABLE 49.

SECTION.	COMPANIES.	Miles.	Kilo-metres.	Gauges	
Sirsa Kot Kapura	Bombay-Baroda & Central India Railway	26	42	1 m. 67 and 1 m.	
Hyderabad Secunderabad. .	Nizam's Railway	6	10	—	—
Bhatinda Kot Kapura. . .	North Western Railway . .	27	44	—	—
Bahramghat Branch . . .	Oudh & Rohilkhund Railway.	17	27	—	—

JAVA. — The example of Java is one of the most interesting.

Following the decision of the Commission of 1871 the State constructed its railways, for economy, to the 1 m. 067 (3′ 6″) gauge. It thus made the large Eastern and Western Railway Systems.

Prior to this the *Dutch Indies Railway Company (Nederlandsche Indische Spoorweg Maatschappij)* had constructed a railway system of the standard-gauge of 4′ 8 1/2″ of which the concession for the first line had been granted in 1862. It ran from the Port of Semarang south to Solo whence it ran to the west to Djokja at 60 km. (37 miles) from there.

The two railway systems of the State railways are separated by this section of 60 km. In 1899 a third rail was laid over this section.

Running of trains of mixed gauges on tracks, with four lines of rail.

In the two classes of lines that we have mentioned the track can be laid with

(1) According to the *Indian Administration Report 1913-1914*.

either three or four rails. The first costs less and avoids complications at junctions; on the other hand the second system allows of the traction of trains of mixed-gauges and of their being shunted in exchange stations much more easily than can be done on a track with three lines of rail on which the drawbar is thrown out of centre. By means of intermediate wagons it is possible to use the locomotives of the two gauges indiscriminately.

On the four-line track of the *Belgian Light Railways* locomotives are used for running on the narrow-gauge (1 m.) with intermediate wagons also running on this narrow gauge (fig. 15).

On sections of the *French Northern Railway* laid with four lines of rail these intermediate wagons run on the standard gauge track (1 m. 435 or 4′ 8 1/2″).

Use is also made of intermediate wagons on the section from Bourbon to Larcy (town station) and on the Vichy-Cunet section of the Paris-Lyons-Mediterranean Railway.

Fig. 15*b*.

c) Traction on tracks with three lines of rail.

Antofagasta Railway (Chili & Bolivia. — We have already seen that this railway has equipped long sections of its line with three rails, enabling rolling stock of metre or 0 m. 76 (2′ 6″) gauge to be used.

In the month of June 1921 the laying of the third rail was completed on the 2′ 6″ section from Antofagasta to Baquedano at km. 96 of the main line, at the junction with the Northern portion of the *Chilian Longitudinal Railway*, laid of metre gauge and worked by the *Antofagasta Railway*.

There has always been a disinclination to run trains of mixed gauges on three rails on account of the want of alignment of the draw-gear, but the *Antofagasta Railway* has made trials with regard to this which have proved completely successful. It runs mixed trains in regular service consisting of a consolidation locomotive of metre gauge hauling, without any intermediate wagon, trains consisting of six 20-ton wagons of 0 m. 76 gauge up gradients of 1 in 33.3. It was only necessary to arrange a flexible coupling be-

Buffer and draw-gear; general view.

Buffer and draw-gear; front view.

Mixed train : locomotive of 2′ 6″ gauge hauling a train of metre-gauge trucks.

Fig. 16. — Traction on mixed metre and 0 m. 76 (2′ 6″) gauges on the Antofagasta Railway (Chili to Bolivia).

tween the locomotive and the vehicles consisting of a draw-gear passing through an opening in the central portion of the automatic coupling with which the rolling stock of the narrow-gauge track is fitted (fig. 16).

This system which works perfectly in practice, is worthy of attention and opens new possibilities for the use of lines of different gauges while avoiding trans-shipment.

The PRUSSIAN STATE RAILWAY, particularly at Kerkerbach, uses intermediate wagons for mixed trains, running on three-rail sections of the line.

Extra cost of the mixed-gauge track over and above that of the narrow-gauge track.

For the sake of clearness we will only give the pre-war figures. Calling :

n, the number of years;
r, the rate of interest;
l, the length of track in miles;
b, the number of branches;
T, the total tonnage per annum;
f, the cost of trans-shipment per ton, if there were no mixed-gauge track (in francs).

The additional charges per mile for interest and depreciation are :

$$\frac{\left(30\,000 + \frac{b\,3\,500}{l}\right) r\,(l + r)^n}{(l + r)^n - l} \text{ per annum}$$

whereas the expense of trans-shipment would have been fT. So long as the first formula is smaller than the second there is obvious advantage in using the mixed-gauge track.

The value given by the first formula increases rapidly with the length, on which the second formula is independent. On the other hand the value given by the second formula increases in direct porportion to T.

The extra cost for adding the standard-gauge track to the narrow-gauge track was estimated, before the war, by the *Belgian Light Railways Company* at 25 000 to 30 000 francs (£1 600 to £2 000 per mile) plus 3 500 francs (£140) for each turn-out.

The *Prussian State Railway* (at Kerkerbach fixed it at 37 500 francs per km. (£2 400 per mile) the traffic being 50 000 tons per annum for the lime kilns.

C) **EXTENSIBLE OR INTERCHANGEABLE AXLES.**

In order to enable vehicles to run on railway systems of different gauges, while avoiding the extra expenditure of a third and even of a fourth rail, attempts have been made to deal directly with the wheels, or the axles, either by moving the wheels together or apart (extensible axles), or by substituting axles corresponding to one gauge for those that correspond to another gauge.

This evidently would be the best solution if it could be carried out in practice, but it is at present only in the experimental stage.

Extensible axles.

The principle of this system consists in using axles to which the wheels can be fixed at two different distances corresponding to one track or the other. In order to fix them in the desired position use may be made of auxiliary power, either hydraulic, pneumatic, or other; or the wheels may be run over a section of track on which the rails are fitted with check rails and of which the gauge is that of the larger track at the commencement; the gauge is then reduced progressively over a length of track till it is diminished

at its end to that of the narrow gauge.

This requires the use of special vehicles which are only advisable when it has been a question of running over a long distance on each of the two tracks. This method has been applied in various countries, it would appear with some success but it has failed to come into general use, not on account of the defects or disadvantages inherent to the system itself, but because it is very little known and there is hesitation in adopting it.

There are, moreover, cases of its application in Europe. A portion of the Russian rolling stock which could subsequently run on the German or Austrian lines of narrower gauge was fitted with axles that suited both the 1 m. 435 and the 1 m. 524 (4′ 8 1/2″ and 5′) gauges.

In China this system was applied on the Tscheng-taï Railway (Shan-si) of metre gauge and 250 km. (155 miles) long, which brings to the Peking-Hankau Railway of 1 m. 445 (4′ 9″) gauge a heavy coal traffic amounting to 2 000 tons per day (1).

Trials have also been made with this system on the Franco-Spanish frontier. But it has the disadvantage of giving the axle an overhang of 50 % from the points at which the loads on the journals are applied.

Bradford and Leeds Tramways (2). — We should mention the success of the double gauge applied on the electric tramways from Leeds to Bradford, the one of 4′ 8 1/2″ and the other of 4′ gauge.

Since about 1910 through cars have been run between the two systems which join at Stanningley. The tracks are connected by a section over which there is a gradual diminution of gauge.

The mechanism for mixed gauges, as applied to the cars of the Bradford Municipality, was invented by Mr. Spencer, its Manager, and Mr. Dawson. The axles are fixed and the wheels, which are fitted with very long hubs, alone are movable.

The mechanism of the Leeds tram-cars was invented by Mr. Watmough, Carriage Superintendent of this Company. The axles are movable and the wheels can slide horizontally and be fixed at the proper distance apart.

Interchangeable axles

Interchangeable axles appear to us to be preferable to extensible axles; they are necessarily stronger and any accident due to their use would have less serious consequences than would be the case with extensible axles.

To effect substitution the vehicle is run into the shed over a pit similar to the Ramsay pit, on which the axles will remain with their wheels and boxes when the body is lifted. It is then only necessary to substitute the axles of the other gauge for those of the first gauge and to lower the body which can be done very quickly.

Mr. Calthrop invented a system of this kind when he was designing his railway for the 0 m. 76 (2′ 6″) gauge and for a uniform load of 5 tons per axle for all the rolling stock. He thus substituted bogies of 2′ 6″ track for the normal axles of the English four-wheel wagons.

More recently, M. Puig has worked out a method of changing axles which has allowed of direct interchangeability between the Spanish Railway System of 1 m. 676 (5′ 6″) gauge and the *French Midi* of normal 1 m. 435 (4′ 8 1/2″) gauge. Wagons of 20 tons capacity were con-

(1) See *Revue générale des chemins de fer* of December 1909, *Le Génie Civil* of 2 October 1909 and the *Annales des ponts et chaussées* of november 1909.

(2) See *The Railway Gazette* of 11 June 1915.

structed before the war and have run without difficulty since 1914, over the *French Midi Railway* system. Trials of this class of arrangement are in progress at the present time (1).

The transverse distance between the horn-plates is the mean of the lengths comprised between the middle points of the axle bearings corresponding to the two gauges, that is to say :

$$\frac{1.940 + 2.212}{2} = 2\text{ m}.076 \text{ or } (6' \, 9\ 3/4'').$$

The thickness of the horn-plates is 20 mm. (3/4″). The suspension springs are on the inside for the standard-gauge and on the outside for the broad-gauge.

The distance between centres of the buffers is also halved between that of the two gauges thus :

$$\frac{1.770 + 1.950}{2} = 1\text{ m}.860\ (6' \, 1\ 1/4'').$$

The bottom of the pit in which the substitution is made is fitted with four lines of rails; the body of the wagon which remains suspended rests then on long narrow wagons running level with the ground on special rails.

The Baltimore & Ohio Railroad (1) (Fixburg, Pa., exchange station). — The goods which it is not desired to unload on the level (at a cost of 50 to 60 centimes [4.8 d. to 5.76 d.] per ton for 10 000 tons par annum) are dealt with by a Ramsay pit, of which the cost of installation was 10 000 fr. (£400). It is provided at the bottom with a four-rail track and at the upper part with small tracks about 0 m. 50 (1′ 8″) gauge which run parallel to and on each side of the pit. Small trolleys running on these auxiliary tracks carry transverse girders. The bodies of the wagons of one of the gauges are taken off their bogies; these are run into the shed, and the bodies are transported a little further where they are transferred to bogies of the other gauge. The cost of labour is from 20 to 25 centimes (1.9 d. to 2.4 d.) per ton, that is to say, less than half the cost of simple trans-shipment on the level (2).

(To be continued.)

(1) See *Bulletin of the International Railway Association*, March 1922, p. 597.

(1) Particulars supplied to the Railway Congress at Berne in 1910.

(2) All these prices are for 1910.

621 .132.1 (.42)]

BRITISH LOCOMOTIVES IN 1923.

DESIGNS AND WORK,

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Figs. 1 to 8, pp. 124 to 127.

I. — Designs.

On the Great Western Railway principal interest attaches to the new *Castle* class of four-cylinder 4-6-0 express locomotives, the first of which is illustrated in figure 1. (See also *a* in table of dimensions appended.) The design, for which Mr. C. B. Collett, O. B. E., has been responsible, is a development of the well-known *Star* class, introduced a dozen years or so ago by Mr. G. J. Churchward. A new boiler is included and larger cylinders, with the result that tractive effort is now 31 626 lb. at 85 % of full boiler pressure, compared with 27 800 lb. in the case of the ordinary four-cylinder class. The new engine therefore has, in view of the high steam pressure used, a greater tractive power than even the Great Northern & North Eastern *Pacific* engines described last year.

Advantage has been taken of the increased length of the frame to provide a longer cab than hitherto usual. This, coupled with the fact that no fittings project into the cab beyond the regulator handle, gives greatly increased space for the driver and fireman. The roof has also been considerably extended and the cab sides fitted with large windows, a further innovation being the provision of tip-up seats for the driver and fireman. It will be noted that the engine is fitted with a copper top to the chimney, and brass safety-valve cover. The cab and splasher beadings are also in brass and the hand rails are now polished. This was the first engine to be turned out since the war with lining, etc., as in pre-war days.

While referring to Great Western locomotives, it may be mentioned that some of the engines belonging to railways now grouped with it have been fitted with Great Western standard boilers and fittings. A number of engines were built at Swindon during the year of various standard classes, principally for mineral and goods traffic. Forming part of the late Cambrian Railways system was a narrow-gauge line in Wales, the Vale of Rheidol (1 ft. 11 1/2 in. gauge). This was operated by 2-6-2 tank engines of special design, and to meet further requirements, Mr. Collett constructed at

Swindon a new engine of the same general class (*b*), including also various features of Great Western practice.

On the Southern Railway reference may first be made to Mr. L. B. Billinton's *Memorial* engine (*c*), London, Brighton & South Coast section, briefly mentioned last year, though it had not then been placed in traffic. This is one of the big 4-6-4 express tank engines used between London and Brighton, but, in addition to bearing the name *Remembrance,* carries a plate lettered « In grateful remebrance of the 532 men of the London, Brighton & South Coast Railway who gave their lives for their country, 1914-1919 ». Further 4-4-0 locomotives have been rebuilt at Brighton, as in the case of No. 55, illustrated in last year's article.

In 1919, Mr. R. E. L. Maunsell designed for the South Eastern & Chatham Railway a 2-6-0 mixed-traffic locomotive. Others have since been constructed, but whereas the class generally has two outside cylinders only, No. 822, built in 1923 (see fig. 2 and *d* in table), has three cylinders, all driving the central coupled axle. The outside cylinders are placed horizontally, while the inside cylinder is inclined at 1 in 8, in order to allow the connecting rod and crosshead to clear the leading coupled axle. The outside piston valves are actuated direct by Walschaert valve gear, the motion from which is carried forward so as to actuate a large 2 1/3 to 1 cross lever with its 1 1/3 to 1 floating lever arranged horizontally across the front of the engine, thus giving the motion to the inside cylinder piston valve. Motion is taken from each outside pendulum lever to the cross levers. In this way the valves of the outside cylinder are kept horizontal and any variation due to expansion of the valve spindle or the wear of the link and pins is not transferred to the valve of the middle cylinder, and, in addition, facility is provided for withdrawing all the piston valves and also the middle piston without dismantling any of the gear. The left-hand outside and middle cylinders have been combined in one casting, and the right-hand cylinder is bolted to these. The engine has, as far as possible, been made identical with the two-cylinder engines of the same class, with the object of comparing three-cylinder and two-cylinder simple engines both as regards performance and cost of maintenance. In order to make the tractive effort the same in each case the boiler pressure of the three-cylinder engine has been reduced to 190 lb. per square inch.

On the London & South Western section a number of older 4-4-0, 4-6-0 and 0-6-0 engines have been modernised by fitting superheater boilers, but otherwise there is nothing further of special interest to record in regard to the three sections of the Southern Railway.

In the case of the London Midland & Scottish Railway three engines call for illustrative reference. On both the London & North Western and Lancashire & Yorkshire sections the Joy valve gear was very widely employed. On several occasions during the last few years, however, engines of some of these classes have had trouble due to the breaking of connecting rods adjacent to the jack-link pivot, and with a view to overcoming this drawback Mr. H. P. M. Beames, mechanical engineer (Crewe), fitted several of the *Prince of Wales* class of inside two-cylinder 4-6-0 engines with an arrangement whereby outside Walschaerts valve gear operated from the outside coupling rod and a return crank will actual inside valves. As will be seen from figure 3 (*e*) the combining lever is driven from the forward end of

the coupling rod, instead of from the piston crosshead, as usual. The motion is transferred to the valve spindle inside the frames by means of a rocking shaft. The running board of the engine has been raised to allow a clearance for the working of the gear, and this incidentally assists in making the side rod lubricators accessible on the top centre.

Figure 4 illustrates a 0-8-4 tank engine (*f*) built at Crewe under the direction of Mr. Beames. This engine, which is an enlarged design of the 0-8-2 side tank shunting class built in December 1911, was designed at Crewe in 1921. The outstanding features are : increased tank and coal carrying capacity, enlarged axle-boxes, slide-bars and horn-blocks, addition of a superheater, mechanical lubrication of all journals, and of cylinders by a *Detroit* displacement lubricator. The engine is fitted with a special design of reversing gear, enabling either wheel or lever to be used at will. The valves are actuated by the Joy gear. These engines have been built for mineral and local passenger working on the heavy gradients in South Wales.

Mention was made in last year's article of a class of 4-6-0 engines built by Mr. W. Pickersgill, mechanical engineer (Glasgow), for service on the steeply graded Callander & Oban line. One of these is illustrated in figure 5 (*g*). In general it is an adaptation of Mr. Pickersgill's three-cylinder 4-6-0 main line design, but with two cylinders only and with 5 ft. 6 in. coupled wheels as compared with the 6 foot wheels of the express engines and the 5 foot wheels of the McIntosh engines which have hitherto worked the Oban line.

In regard to other London Midland & Scottish locomotives mention may be made of an improved 0-8-0 mineral class (*h*) introduced by Mr. G. Hughes. The design is a development of that introduced in 1916, but fitted with a large cab and various modifications, including Mr. Hughes' « top and bottom header » superheater.

Further 4-6-0 four-cylinder engines to Mr. Hughes' design have been constructed during the year, also engines of standard classes on all sections.

Figure 7 (*i*) illustrates, by line diagram, a rebuilt locomotive possessing great historic interest. As No. 11, Glasgow & South Western Railway, this engine was the first four-cylinder non-compound locomotive to be placed in service on any British railway. This was in 1897, Mr. J. Manson being the designer. It had then two inside cylinders, 14 1/2 by 26 inches, and two outside cylinders, 12 1/2 by 24 inches. Although it has lasted so many years the engine, owing largely to its relatively small boiler, was not markedly successful. As reconstructed by Mr. R. L. Whitelegg, however, and fitted with a large superheater boiler, it has been converted into a modern design of considerable capacity. As rebuilt, all cylinders are 14 inch diameter, but the varying strokes remain. By the use of crossed ports one piston valve controls the steam distribution of two cylinders on one side. Stephenson link motion is retained.

It is now necessary to consider developments on the London & North Eastern Railway. Here principal interest attaches to Mr. Gresley's « booster »-fitted 4-4-2 engine No. 1419, Great Northern section, shown in figures 6 and 8 (*j*). The use of the « booster » converts the trailing wheels of the locomotive into a pair of driving wheels which supply independent and, therefore, augmenting power. The booster is a separate two-cylinder engine placed below the footplate of the locomotive. To provide sufficient space for

Fig. 1. — New four-cylinder 4-6-0 locomotive, Great Western Railway.

Mr. C. B. Collett, O. B. E., chief mechanical engineer.

Fig. 2. — Three-cylinder mixed-traffic locomotive, Southern Railway.

Mr. R. E. L. Maunsell, C. B. E., chief mechanical engineer.

Fig. 3. — 4-6-0 inside cylinder locomotive fitted with outside Walschaerts valve gear, London Midland & Scottish Railway (L. & N. W. Section).

Mr. H. P. M. Beames, mechanical engineer (Crewe).

Fig. 4. — 0-8-4 super-heater tank engine, London Midland & Scottish Railway (L. & N. W. Section).

Mr. H. P. M. Beames, mechanical engineer Crewe).

Fig. 5. — 4-6-0 steep-gradient locomotive, London Midland & Scottish Railway (Caledonian Section).

Mr. W. Pickersgill, C. B. E., mechanical engineer (Glasgow).

Fig. 6. — 4-4-2 engine fitted with « booster » to trailing wheels, London & North Eastern Railway (Great Northern Section).

Mr. H. N. Gresley, C. B. E., chief mechanical engineer.

the apparatus the frames of the engine have been lengthened at the footplate end. The booster engine has two inside cylinders, 10 inch diameter by 12 inch stroke.

Steam distribution is by piston valves with direct valve motion. On the driving shaft of the booster is a pinion wheel, from which, through an intermediate, or idler pinion wheel, power is supplied to the trailing carrying wheels of the locomotive, through a third pinion wheel fixed on the trailing axle. The three pinion wheels are all of different diameters, so arranged that the revolutions of the trailing carrying wheels are less than those of the driving shaft. The diameter of the carrying wheels driven by the « booster » is 3 ft. 8 in.; consequently the successful application of the booster is dependent upon a comparatively low speed, such as when the train starts, or is climbing a gradient.

The idler gear is secured to the base of the « booster » by a rocking arm; when it is desired to operate the « booster » gear, the driver, by means of compressed air apparatus operating a piston attached to a bell crank, throws the idle pinion into mesh and establishes connection between the driving shaft and the carrying wheels. The driver then admits steam to the booster cylinders by means of an air operated regulator, and the booster operates. When steam is cut off from the booster engine, the idler gear is taken out of mesh by means of spring-controlled mechanism, and the trailing axle is thus relieved of the retarding action, which would result from being in engagement with the booster driving apparatus. So far as the booster apparatus is concerned, little difference is made by it in the external appearance of the locomotive — the provision of an air compressor on the smokebox on one side and a live steam pipe along on side, and exhaust pipe on the other side above the running board, are to be seen. Advantage has been taken of the lengthening of the footplate to provide No. 1419 with an improved type of cab having a longer roof and side windows.

In regard to other developments, further engines of Mr. Gresley's 4-6-2 class have been placed in service, and in view of the great satisfaction they have given, twenty more are under construction. On the Great Eastern section some of the earlier 4-4-0 engines have been fitted with larger boilers, and during 1923 several new engines (*k*) were built to the improved design for working heavy trains on routes where 4-6-0 engines are not allowed or are not usually employed. Some new 0-4-0 tank engines were built for use in docks served by the North Eastern section.

During the year a number of London & North Eastern engines have been worked, in some cases regularly, on routes other than those of the section to which they belonged, and to some extent the same thing has occurred on the London Midland & Scottish Railway. On the former line passenger engines are now painted green and goods and tank engines black, in each case lettered L. & N. E. R. or L. N. E. R. above a large numeral with a letter indicating the section to which the engine belongs. On the London Midland & Scottish Railway the engines are being renumbered, Nos. 1-4999 being reserved for Midland Division engines, Nos. 5000-9999 for late London & North Western locomotives, Nos. 10000-11999 for Lancashire & Yorkshire engines, and above 12000 for Scottish engines. Red has been adopted as the colour for passenger engines and black for goods. Engines taken over by the Great Western are given numbers according to class in the Great Western series. On the South-

ern Railway no definite decision has been announced, though some engines have been painted green and lettered « Southern », with a numeral below. Neither has any system of classification yet been made.

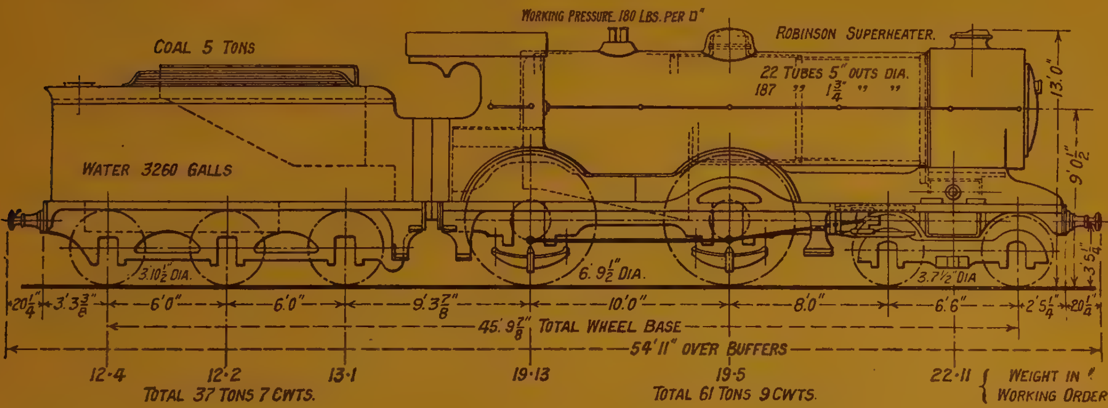

Fig. 7. — Four-cylinder locomotive, as reconstructed at Kilmarnock works, London Midland & Scottish Railway (Glasgow & South Western Section).

Mr. R. L. Whitelegg, then mechanical engineer (Kilmarnock).

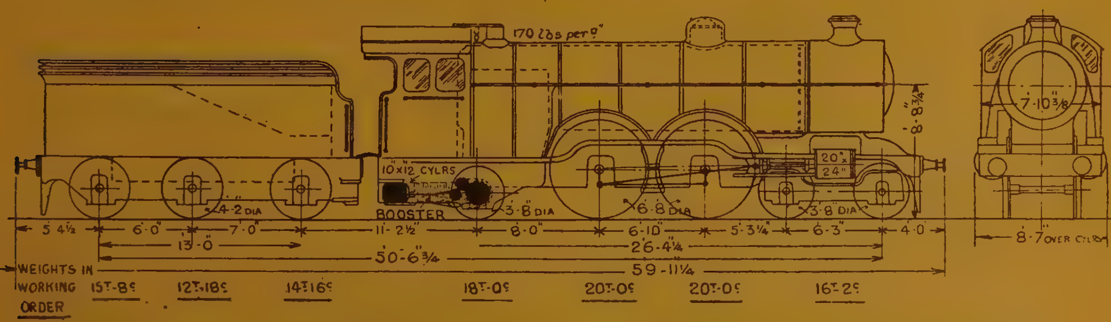

Fig. 8. — 4-4-2 « booster » locomotive, London & North Eastern Railway (Great Northern Section).

Mr. H. N. Gresley, C. B. E., chief mechanical engineer.

With regard to other railways, the only engines calling for notice are those belonging to Irish lines. On the Great Southern & Western Railway a four-cylinder 4-6-0 locomotive, No. 400, designed in 1916 by the late Mr. E. A. Watson, together with three others subsequently built, was followed in 1923 by several others. In designing these further engines Mr. J. R. Bazin included certain modifications, and three have been built with superheaters (*l*) and three without. Larger tenders have also been fitted. Mr. Bazin also rebuilt some 2-6-0 goods engines with a leading truck instead of a radial axle, and with new

Belpaire boilers and other improvements.

For goods traffic on the Dublin & South Eastern Railway Mr. G. H. Wild introduced a 2-6-0 superheater engine (*m*), fitted with Belpaire firebox, and on the Belfast & County Down Railway Mr. J. L. Crosthwait placed in service a 0-6-4 tank engine (*n*) specially designed to enable very sharp curves to be taken. On the Northern Counties line further 4-4-0 engines have been brought into use, while on the Great Northern line Mr. Glover has rebuilt several older engines with superheater boilers, etc.

II — Work

During 1923 a number of accelerations in war-reduced express train schedules were made, and various new runs introduced.

In the summer time-tables of 1923, therefore, the London Midland & Scottish Railway had 68 non-stop runs of between 100.6 and 219.5 miles in length; the London & North Eastern, 51 of between 103 and 188.2 miles; and the Great Western, 27 of between 102.3 and 225.7 miles. The longest on the London Midland & Scottish Railway was from London (Euston) to Colwyn Bay (North Wales coast), run on Saturdays only, when the usual North Wales holiday express, booked from Euston to Prestatyn (205.5 miles) was preceded by a relief running 14 miles further. On the London & North Eastern Railway the run of 188.2 miles between London (King's Cross) and York was a new development in 1923, while the second longest, between King's Cross and Leeds (185.7 miles) was also a novelty for the year. The Great Western record was the world-famous Paddington-Plymouth run of 225.7 miles, and on Saturdays, if this train was divided, the advance portion was somentimes extended to Devonport, a mile further.

These runs gave averages as follows :

Euston-Colwyn Bay	51.0 miles per hour.	219.5 miles.
Euston-Prestatyn	51.6 — —	205.5 —
King's Cross-York	53.8 — —	188.2 —
King's Cross-Leeds	54.4 — —	185.7 —
Paddington-Plymouth (North Road)	54.8 —	225.7 —
Paddington-Devonport	55.8 — —	226.9 —

Seeing that each of these journeys included severely graded sections on stages where, for other reasons, the highest averages could not be maintained, it was only to be anticipated that each company had other 100-mile runs giving still higher averages, the best being as follows :

L. M. S. R.	Birmingham-Willesden Junction	109.0 miles.	59.2 miles per hour.
L. N. E. R.	London (Marylebone)-Leicester	103.1 —	56.8 — —
G. W. R.	London (Paddington)-Bristol	118 3 —	59.2 — —

The last mentioned (two trains) also gave a slip service to Bath, 106.9 miles at 61.1 miles per hour. The Southern Railway had no runs exceeding 100 miles in length.

In regard to fastest runs, the Great Western Railway, in 1923, introduced a new one between Swindon and Paddington of 77.3 miles in 75 minutes, average 61.8 miles per hour, thus improving, and

for a longer distance but over a comparatively easy route, upon the previous records on the London & North Eastern Railway between Darlington and York, 44.1 miles in 43 minutes, and between Leicester and Nottingham (Arkwright Street), 22.6 miles in 22 minutes, both at 61.5 miles per hour average.

Other very fast runs were :

London Midland & Scottish Railway.

Birmingham-Coventry	18.9 miles.	19 minutes.
Forfar-Perth	32.5 —	34 —
Kettering-St. Pancras	72.0 —	76 —
Euston-Wilmslow	176.9 —	213 —
Euston-Birmingham.	112.9 —	120 —
Euston-Crewe	158.1 —	169 —

London & North Eastern Railway.

Aylesbury-Leicester.	65.1 miles.	65 minutes.
Marylebone-Leicester	107.6 —	114 —
King's Cross-Grantham	105.5 —	114 —
Grantham-Doncaster	50.5 —	54 —

Great Western Railway.

Paddington-Bristol	117.6 miles.	120 minutes.
Paddington-Exeter	173.7 —	179 —
Paddington-Taunton.	142.9 —	148 —
Reading-Taunton	106.9 —	112 —
Reading-Exeter	137.7 —	145 —
Paddington-Torquay	199.7 —	215 —
Paddington-Birmingham	110.6 —	120 —

Southern Railway.

Dorchester-Wareham	15.0 miles.	16 minutes.
Tonbridge-Ashford	26.5 —	28 —

Many of these runs are made regularly with reasonably heavy trains, so that their very high average speeds often entailed severe demands on the engines, though, obviously, they could not be expected with maximum loads. During the year the writer travelled with several of the trains having averages of over 60 miles per hour, though for various reasons some of them did not quite meet requirements.

In view of the fact that the Great Western 61.5 miles per hour schedule between Swindon and Paddington was the principal speed novelty of the year, pride of place must be given to a record with this train, more especially as the engine was No. 4073, *Caerphilly Castle* (fig. 1). The load was about 250 tons, and weather conditions good. The most notable feature was that speed rarely exceeded 75 miles per hour, and then not

to any great extent. Starting from Swindon, the 24.2 miles to Didcot were run in 24.1 minutes, the 17.1 miles thence to Reading (passed at about 70 miles per hour) occupied 15.2 minutes. Slough was passed 15.1 minutes later (17.5 miles), and the remaining 18.5 miles to Paddington, including an easy approach to the terminus and moderate running to avoid too early an arrival, were completed in 18.7 minutes. The 77.3 miles were thus covered in 73.1 minutes, against 75 minutes allowed, and that without very high maximum speeds.

Two runs on the 8.59 p. m. from Darlington to York, which is allowed 43 minutes for the 44.1 miles, start to stop — a schedule which was, for many years, the fastest in the British Isles — must now be mentioned, though in neither case was time kept, mainly due to storm and wind conditions which were very adverse. The same engine was concerned on both occasions, a North Eastern three-cylinder 4-4-2, No. 2166 (1). This train is a much harder one to work than it was before the war, as it now includes a restaurant car make-up of at least 220 tons, and is not infrequently heavier, as on the first run to be described, when it would be about 260 tons. With this load No. 2166 took 4.2 minutes to pass Croft Spa (2.6 miles). Thence to Thirsk, 19.3 miles were run in 19.1 minutes, and the 16.7 miles thence to Beningbrough in 15.6 minutes. The remaining 5.5 miles to York took 6.4 minutes, but this included running steadily for practically the whole length of the long main platform to the South end of York station, so that, allowing for stormy conditions, the engine had really done well to complete its run in 45.3 minutes, against 43 allowed.

(1) See *Bulletin of the International Railway Congress Association*, April 1912.

On the second run, also in adverse weather conditions and with a load of 240 tons, No. 2166 took 4.1 minutes to pass Croft Spa; the sections thence to Thirsk and Beningbrough occupied practically the same time as on the other run, almost to the second, and the final run to the south end of the long platform at York was a shade faster, so that the 44.1 miles from Darlington had taken exactly 45 minutes, a slight improvement on the previous run. The fact that neither quite realised requirements was fully accounted for by the stormy conditions prevailing on each occasion.

The writer had no opportunity of timing the London & North Eastern (Great Central) 65.5 miles per hour run, but had two journeys with the train booked to cover the 65.1 miles between Aylesbury and Leicester in 65 minutes. In both cases, 4-4-0 superheater engines of the « improved Director » class were concerned, the load about 165 tons and weather conditions fair.

No. 508, *Prince of Wales*, completed the first stage to Aylesbury, via the severely graded Metropolitan route, in 46.5 minutes (38 miles). Starting again, the 8.8 miles to Grendon-Underwood Junction occupied 11.6 minutes, but thereafter speed ranged usually at about 65-70 miles per hour, and occasionally faster. The 22.3 miles to Woodford and Hinton occupied 23.9 minutes, thence to Rugby (14.1 miles), 12.6 minutes, and the remaining 19.9 miles to Leicester, 18.1 minutes. Even then, however, the 65.1 miles from Aylesbury to Leicester had occupied 66.2 minutes against 65 allowed. On the second run, No. 505, *Ypres*, had covered the 38 miles from London (Marylebone) in 44.9 minutes. Starting again, the 8.8 miles from Aylesbury to Grendon-Underwood were run in 9.9 minutes, the 22.3 miles thence to

Woodford occupied 22.9 minutes, the 14.1 miles to Rugby, 13.6 minutes, and the 19.9 miles to Leicester, 19 minutes. Consequently, the 65.1 miles had occupied 65.4 minutes.

As one of the novelties of the year, as well as the longest non-stop journey made by the writer, reference must now be made to the Harrogate Pullman express introduced by the London & North Eastern Railway. This consists normally of two first class and four third class Pullman cars, usually with one or more vans, and is booked non-stop between King's Cross and Leeds, 185.7 miles, for which 205 minutes are allowed. As the route is very severely graded between Doncaster and Leeds, with many service slacks, notable work is called for elsewhere, while the main line section is far from easy, though not extreme. On many occasions this train has been worked by Great Central four-cylinder 4-6-0 locomotives, and the writer's record was obtained behind one of them, No. 1166 *Earl Haig* (1) with the six Pullmans and two vans, about 300 tons.

Starting well on the climb through tunnels, Finsbury Park was passed in 5.8 minutes (2.5 miles), and the summit at Potter's Bar in 14.7 minutes (10.2 miles). Thence to Hitchin, with an intermediate relaying slack, 19.2 miles were run in 23.1 minutes, and the 27 miles onwards to Huntingdon in 23.5 minutes, a fine burst of sustained high speed, without, however, extreme maxima. At the top of Abbott's Ripton bank speed did not fall below 55 miles per hour, and when passing through Peterborough at the usual slow speed 17.6 minutes had been taken from Huntingdon (17.5 miles), 64.2 minutes from Potter's Bar summit (63.7 miles) and 84.7 minutes from the start (76.4 miles), with one relaying slack. The next stage of 23.7 miles to Stoke summit, largely one continuous grade at about 1 in 200, was covered in 27.1 minutes. A second relaying check was experienced near Grantham, but that station was passed in 33.9 minutes from Peterborough and in 118.6 minutes from London (105.5 miles). Newark (14.6 miles) was passed in 13.1 minutes; Retford, 18.1 minutes later (18.6 miles), and Doncaster in a further 16.9 minutes (17.3 miles), so that the 50.5 miles from Grantham had been run in 48.1 minutes, 79.6 miles from Peterborough in 82 minutes, 143.3 miles from Potter's Bar summit in 146 minutes, and 156 miles from the start in 166.7 minutes. From passing Doncaster at reduced speed the severely graded and complicated 19.7 miles to Wakefield were covered in 23.7 minutes, and the final 10 miles, even more complex, occupied 16.5 minutes. Actually, 1 minute over schedule time had been taken, but with two relaying slacks in addition to usual speed orders.

No opportunity was available for recording one of the London-York non-stops, but these were regularly made with fair loads by Great Northern 4-4-2 engines without difficulty.

On the Great Western Railway the longest non-stop journey made was that between Paddington and Exeter; though this involved the very unusual experience of loss of time, largely explained by the very high wind. Four-cylinder 4-6-0 of the *Star* class (1), No. 4065, *Evesham Abbey*, built in 1922, had a load of

(1) See *Bulletin of the International Railway Congress Association*, January, February, March 1920.

(1) See *Bulletin of the International Railway Congress Association*, April 1911.

340 tons to work to Exeter, 173.7 miles in 180 minutes, so that to take 189.2 minutes was in itself no mean achievement. The first 18.4 miles required 22 minutes, and the 17.6 miles thence to Reading (reduced speed for junction) 17.9 minutes. Onwards, the gradients become harder, though not extreme, so that the 17 miles to Newbury occupied 19.1 minutes. Thence to the slack at Westbury the 42.5 miles were covered in 43 minutes. At Frome reduced speed is again necessary, so that these 5.7 miles occupied 7.9 minutes. The next 41.7 miles to Taunton were run in 46 minutes. The climb of 10.9 miles to the summit tunnel took 13.2 minutes, and the remaining 20 miles to the Exeter stop, mainly downhill, were run in 19.6 minutes.

A return journey behind an older engine of the same class, No. 4019, *Knight Templar*, included interesting features. At the start the load included the Penzance-Glasgow and Aberdeen sleeping car and through carriages, thus bringing the London load of 280 tons to a total of 395 tons as far as Westbury. The high wind of the down journey still constituted a difficulty. The adverse 20 miles to the first summit occupied 29.5 minutes, including a permanent way repair check, but by running the remaining 10.9 miles down to a stop at Taunton in 9.9 minutes, the 30.9 miles from Exeter were completed in 39.4 minutes. From Taunton to Frome (service slack) the 41.7 miles were run in 54.3 minutes, and to the stop at Westbury, 47.5 miles in exactly 60 minutes. With the load reduced to 280 tons, No. 4019 passed Newbury (42.5 miles) in 45 minutes, with an intermediate permanent way repair check, Reading at the usual reduced speed, 16.7 minutes later (17 miles), and reached Paddington in a further 36.9 minutes (36 miles), so that the 95.5 miles from Westbury had occupied 98.6 minutes.

On the Birmingham main line a similar engine, No. 4016 *Knight of the Golden Fleece*, had 170 tons for Birmingham and beyond, 55 tons for the Leamington slip and 50 tons for the Princes Risborough slip. With a total of 275 tons the 26.5 miles to a stop at High Wycombe were covered in 32.4 minutes, including easy running over the first 5 miles. The 8.2 miles to Princes Risborough, where the load was reduced by slipping to 225 tons, were covered in 9.9 minutes, and the next 32.8 miles to Banbury in 30.2 minutes. Thence to Leamington (slow speed and load reduced to 175 tons) the 19.8 miles occupied 17.2 minutes. The final 23.3 miles into Birmingham were run in 26.9 minutes, with one intermediate check. The 84.1 miles from High Wycombe had therefore been completed in 84.2 minutes.

On a return journey another engine of the same class, No. 4028, *King John*, had a load of 270 tons throughout, for a 120 minute schedule for 110.6 miles of by no means easy route. Leamington was passed in 26.3 minutes (23.3 miles), Banbury 23.2 minutes later (19.8 miles), the 41 miles to High Wycombe (reduced speed) in 41.5 minutes, and the final 26.5 miles, with a permanent way check and slow running for the last 5 miles, in 31.6 minutes, so that actually the complete run of 110.6 miles had taken 122.6 minutes.

On the London & North Eastern Railway, apart from journeys already mentioned, principal interest attaches to some records on the East Coast route, omitting stages already covered incidentally.

With one of the night sleeping car trains a North Eastern three-cylinder

4-4-2 No. 2195 (1), and a load of 330 tons, passed Thirsk (check) in 28.2 minutes from York (22.2 miles), and Darlington 23.2 minutes later (21.9 miles), thus taking 51.4 minutes for the run of 44.1 miles, with a considerable load and under bad weather conditions and including a check. Thence to Newcastle was subject to various delays, so that to cover the 36 miles in 44.6 minutes involved good work. An older but similar engine, No. 714, with 300 tons, continued to Edinburgh. The relatively slow speed 16.6 miles to Morpeth were covered in 23.9 minutes. Thence to Alnmouth Junction 18.2 miles occupied 19.4 minutes, and the 32.1 miles to Berwick (slack) 35.1 minutes, so that the 67.9 miles from Newcastle had been covered in 80.4 minutes, over a route involving several regular slacks and far from easy as regards gradients. North of Berwick the gradients become harder, but Grant's House (16.2 miles) was passed in 22.9 minutes, speed on the long bank never falling below 35 miles per hour, and the remaining 41.3 miles to Edinburgh (Waverley) were run in 48.5 minutes, thus completing the 125.4 miles from Newcastle in 149.6 minutes, with severe gradients and a number of regular slacks.

Coming south, No. 736 of the same class, with 300 tons, passed Dunbar in 33.8 minutes (29.3 miles), and after climbing the very hard Cockburnspath bank passed Grant's House 18.6 minutes later (12 miles), with a minimum speed, on the steepest part at 1 in 96, of 25 miles per hour. Thence to Berwick (passed slowly and with an intermediate relaying slack) the 14.2 miles took 20.6 minutes, so that the 57.5 miles from Edinburgh had been run in 73 minutes. The 32.1 miles to Alnmouth Junction were run steadily in 38.2 minutes, and the 18.2 miles to Morpeth in 20.7 minutes, the final 17.4 miles to Newcastle taking the unusually fast time for this section of 19.4 minutes. The 67.9 miles from Berwick had thus taken 78.3 minutes, and the 125.4 miles from Edinburgh 151.2 minutes.

On a slower schedule than that of the special Darlington-York runs previously described, No. 717, with 330 tons load, covered the 38.6 miles from leaving Darlington to passing Beningbrough in 39.9 minutes, but delays into York caused the complete run of 44.1 miles to take 48 minutes. The train was then taken on by one of the Great Northern three-cylinder 4-6-2 engines introduced in 1922 (1). No. 1476 had, however, an increased load of 420 tons. The 13.8 miles to Selby (slowly over swing bridge) occupied 17.6 minutes, and with an intermediate check Doncaster (18.4 miles) was reached 20.6 minutes later. Starting again, No. 1476 passed Retford (17.4 miles) in 21.5 minutes (with an intermediate check), Newark 19.5 minutes later (18.5 miles) and covered the 14.6 miles to Grantham in 17.3 minutes. Here an ordinary 4-4-2, No. 1443, replaced No. 1476, with the same heavy load. 10.3 minutes were taken to climb to Stoke summit (5.4 miles). The 23.7 miles to passing Peterborough slowly were then run in 26 minutes, with an intermediate permanent way slack at the fastest point, after attaining 84 miles per hour. Further stages were : Peterborough-Huntingdon, 17.5 miles, 20.6 minutes; Huntingdon-Potter's Bar, 46.2 miles, 52 minutes (a fairly difficult

(1) See *Bulletin of the International Railway Congress Association*, April 1912.

(1) See *Bulletin of the International Railway Congress Association*, March 1923.

stage), Potter's Bar-King's Cross, 12.7 miles, 16.4 minutes, with checks approaching the terminus. The 105.5 miles from Grantham had thus been covered in 125.3 minutes, and the 76.4 miles from Peterborough in 89 minutes.

In the case of the West Coast route the writer's records cover most sections between London and Glasgow and Perth, but in stages by various trains. With a load of 330 tons a London & North Western two-cylinder 4-6-0, No. 1584, *Scotia*, after stopping at Willesden Junction, passed Tring summit in 33.8 minutes (26.3 miles), covered the downhill 15 miles to Bletchley in 14.3 minutes, and reached Rugby (35.9 miles) 39 minutes later (with an intermediate check), thus completing the 77.2 miles from Willesden in 87.1 minutes. A similar engine, No. 2359, *Hermione*, continued to Crewe, taking 53.3 minutes to pass Stafford (51 miles), completed the climb of 14 miles to Whitmore in 16.2 minutes, and reached Crewe, after signal delays approaching, 11.7 minutes later (10.5 miles), thus taking 81.2 minutes for the 75.5 miles from Rugby. Taking up the route again at Preston, a third engine of the same class, No. 1132, *Scott*, with 270 tons, covered the 21 miles to Lancaster (a fairly difficult stage), start to stop, in 32.6 minutes. The increasingly difficult 26.1 miles to Tebay were run in 41.2 minutes, and the 5.4 miles to Shap summit (4 miles at 1 in 75) in 11 minutes, without assistance. The 13.5 miles down to a stop at Penrith occupied 15.1 minutes, so that the 51.1 miles from Lancaster, including the hardest portion of the entire route, had taken 67.3 minutes. The 17.9 miles to Carlisle occupied 19.5 minutes, start to stop.

Still considering the work of London & North Western locomotives, the return journey from Carlisle to Crewe was devoid of interest, owing to the number of stops made, delays and temporary single-line working on one section. At Crewe another two-cylinder 4-6-0, No. 433, with 290 tons, passed Stafford in 30.7 minutes from Crewe (24.5 miles), and completed the 51 miles to Rugby in 56.5 minutes. The 35.9 miles to passing Bletchley were run in 41 minutes, the 15 up-hill miles to Tring occupied 16.5 minutes, and the 26.3 easy miles to passing Willesden Junction at speed were covered in 26.1 minutes, so that 77.2 miles from Rugby had taken 83.6 minutes. Delays into the terminus caused the last 5.4 miles to take 11.2 minutes.

In Scotland two *Caledonian* 4-4-0's, Nos. 114 and 135 [1], with 380 tons from Carlisle, were stopped outside Kirtlebridge by signal in 20.2 minutes (16.6 miles). Starting again, Beattock was passed at full speed in 26.2 minutes (23.1 miles), and the ascent of 10 miles at 1 in 75 was completed to a stop at the Summit in 17.7 minutes, a remarkably good time. Here, No. 135 was detached, No. 114 taking on the full load to Stirling. The 23.7 miles of fairly easy route to Carstairs occupied 24 minutes, and at Law Junction (34.3 miles) 35 minutes had been taken. The remainder of the route is very complex, with many curves and junctions, and some adverse gradients, but Stirling was reached in 73.4 minutes from Summit, and in 134.5 minutes from Carlisle (117 miles), apart from time occupied by stops, which brought the time to about 142 minutes against 147 allowed. With the load reduced to 330 tons, No. 114, with banking assistance at the start, covered the hard 17 miles to Gleneagles in 23.2 mi-

(1) See *Bulletin of the International Railway Congress Association*, April 1911.

nutes, and ran down to Perth thence in 20 minutes (15.1 miles).

Coming south from Glasgow No. 96, a new 4-4-0, with 190 tons, after stopping at Motherwell, covered the 16 miles to a stop at Carstairs in 27.6 minutes. The load was then increased to 300 tons. The ascending 23.5 miles to Summit occupied 35.7 minutes, and 10 miles down to a stop at Beattock were covered very carefully in 14 minutes. Beattock to Lockerbie and Lockerbie to Carlisle, in each case start to stop, occupied, respectively, 13.6 minutes (13.1 miles) and 30.6 minutes (25.8 miles).

On the Glasgow & South Western route between Carlisle and Glasgow, 4-6-0 No. 512, with a load of 240 tons, covered the start to stop stages, Carlisle to Annan (17.6 miles) in 23.6 minutes, and Annan to Dumfries (15.5 miles) in 20.1 minutes. Starting again, the 36.9 miles, mainly of adverse grades, to New Cumnock occupied 47.1 minutes. The easy 21.2 miles down to Kilmarnock were delayed by a tunnel repair slack and one for relaying, and therefore took 28 minutes, the complete time for the 58.1 miles from Dumfries being 73.9 minutes. From Kilmarnock the very steep grades to Dunlop took 16.2 minutes (7.6 miles), the remaining 16.7 miles into the Glasgow terminus occupying 21 minutes.

On a return journey No. 501, another 4-6-0, with 180 tons, passed Dunlop (16.7 miles hard) in 25 minutes, reaching Kilmarnock (7.6 miles) 9 minutes later. Here No. 498 of the same class replaced No. 501 for the non-stop run to Carlisle. To New Cumnock (21.2 miles) 35 minutes were taken, the 36.9 miles down to Dumfries occupying 40 minutes. Annan was passed 16.6 minutes later (15.5 miles), the remaining 17.6 miles to Carlisle taking 21.8 minutes, so that the 91.1 miles from Kilmarnock had been run in 113.5 minutes.

In the case of the Southern Railway, a return journey between Waterloo and Exeter may first be summarised. No. 743, large 4-6-0 of the latest class, had a load of 250 tons, to work over a route by no means easy. Soon after leaving London a relaying slack was experienced, so that 31.4 minutes were taken to pass Woking (24.4 miles). The 23.5 miles thence to passing Basingstoke occupied 25.1 minutes, Andover (18.8 miles) was passed 18.9 minutes later, and the 17.7 miles down to the Salisbury stop occupied 17.5 minutes, so that while the first few miles gave only ordinary times, the later portion of the journey was performed very smartly, the 60.4 miles from Woking having taken only 61.4 minutes, and the complete run of 83.8 miles, 92.9 minutes. After changing enginemen, but with the same engine and load, Templecombe (28.4 miles) was passed in 33.7 minutes, but at Axminster, approaching the foot of Colyton bank, the 32.6 miles from Templecombe had been run in 34.5 minutes. The 7.7 miles to Honiton tunnel, at the summit, were mounted in 12 minutes, while a steady run down the bank gave 21 minutes for the remaining 19.3 miles. The 88 miles from Salisbury had thus taken 101.2 minutes, over a route distinctly harder than that from London to Salisbury.

Returning, a similar engine, No. 738, with 300 tons, passed Honiton summit (19.3 miles) in 27.5 minutes, and with one slack ran to a stop at Templecombe (40.3 miles) in 48.1 minutes. Signal checks spoiled the run to Salisbury, but good work was done beyond with the same engine and changed enginemen. From Salisbury to Andover the hard 17.1 miles took 22.6 minutes, but on the comparatively easy route beyond, the

47.5 miles to passing Weybridge occupied only 46.4 minutes. Checks beyond caused the 19.2 miles into London to take 25.7 minutes, but even then the 83.8 miles from Salisbury to Waterloo had been completed, with a considerable load, in 94.7 minutes.

On the London, Brighton & South Coast section of the Southern Railway, principal interest attaches to three 60-minute journeys between Victoria and Brighton, all with large 4-6-4 express tank engines, two with No. 327 on the down *Southern Belle* Pullman Car express (10 cars, about 350 tons). On the first occasion, with the usual steady running, the 10.5 miles to pass East Croydon took 17.3 minutes. Thence to Three Bridges (19.1 miles) occupied 20.9 minutes. The 8.4 miles to Haywards Heath, including a relaying check, took 10 minutes, and the remaining 12.9 miles to Brighton (very easy run in) took 13.9 minutes, so that 62.1 minutes had been taken for the complete run of 50.9 miles. On the second run with the same load and engine, also time was not kept, but there was a slight signal check as well as the relaying slack mentioned. Times for the sections mentioned were : Victoria-East Croydon (18 min.), East Croydon-Three Bridges (21.2 min.), Three Bridges-Hayward's Heath (10.1 min.), Hayward's Heath-Brighton (15 min.), total 64.3 minutes. On a return journey No. 331 of the same class had a load of 300 tons, with which it made the run easily in the scheduled time. Hayward's Heath was passed in 16.6 minutes (12.9 miles, partly adverse), but the 27.5 miles thence to East Croydon were run in 27.8 minutes. The remaining 10.5 miles into London were covered very easily in 15.6 minutes, thus making exactly 60 minutes for the 50.9 miles.

On the North British route between Edinburgh and Glasgow, with a heavy train, including several long-distance sleeping cars and through carriages, mixed traffic 4-4-0 No. 867 (North British section), with 270 tons and in a very high wind and under storm conditions, was unable to complete the run of 47 1/4 miles in the 60 minutes schedule. The straightforward section from Haymarket to Cowlairs, 44.3 miles, therefore occupied 59 minutes, the remaining 8 minutes being required to traverse the Edinburgh tunnels and descend the 1 in 45 Cowlairs bank into the Glasgow terminus. A much more interesting run was one the other way, when a 6 feet 4-4-0 of the *Glen* class, No. 242, had a good 310-ton train. Banking assistance was, of course, provided from Glasgow (Queen Street) to Cowlairs, passed in 6.2 minutes (1.5 miles mostly at 1 in 45). A conditional stop was made at Lenzie, and the 18.8 miles thence to the Polmont stop were run in 24.7 minutes. Thence to a stop at Haymarket occupied 24.8 minutes (20.7 miles).

LEADING DIMENSIONS OF LOCOMOTIVES ILLUSTRATED AND DESCRIBED.

T = Tank engine. R = Rebuilt. B = Booster-fitted.

Reference.	Figure.	RAILWAY.	Type.	Cylinders. Diameter and stroke (inches).	Diameter of coupled wheels.	Heating surface (square feet).			Grate area (square feet).	Steam pressure (lb. per square inch).	Weight (engine only) in working order (tons).
						Tubes.	Fire box.	Super-heater.			
(a)	1	Great Western	4-6-0	16 × 26 (4)	6′ 8 1/2″	1 885.62	163.76	262.62	30.28	225	79.8
(b)	...	" " (Vale of Rheidol).	2-6-2 T	11 1/2 × 17,	2′ 6″	...	...	...	...	165	25
(c)	...	Southern (L. B. & S. C. Section)	4-6-4 T	22 × 28	6′ 9″	1 664.48	152.08	388	26.68	170	98.5
(d)	2	Southern (S. E. & C. Section). .	2-6-0	16 × 28 (3)	5′ 6″	1 390.6	135	285	25	190	62.7
(e)	3	L. M. & S. (L. N. W. Section) .	4-6-0 R	20 1/2 × 26	6′ 3″	1 375.8	135.8	304.4	25	175	...
(f)	4	L. M. & S. (L. N. W. Section) .	0-8-4 T	20 1/2 × 24	4′ 5 1/2″	...	...	...	23.6	185	88
(g)	5	L. M. & S. (Cal. Section)	4-6-0	19 1/2 × 26	5′ 6″	1 707	116	...	21.9	185	62.6
(h)	...	L. M. & S. (L. & Y. Section) . .	0-8-0	21 1/2 × 26	4′ 6″	1 482	195	552	25.6	180	66.2
(i)	7	L. M. & S. (G. & S. W. Section)	4-4-0 R	14 × { 24 (2) 26 (2)	6′ 9 1/2″	1 444	148	211	27.6	180	61.4
(j)	6, 8	L. & N. E. (G. N. Section) . . .	4-4-2 B	20 × 24 B 10 × 12	6′ 8″ 3′ 8″	1 824	141	568	31	170	74.1
(k)	...	L. & N. E. (G. E. Section) . . .	4-4-0 R	19 × 26	7′ 0″	1 379.7	128.2	180.5	21.6	180	55.5
(l)	...	G. S. & W. (Ireland)	4-6-0	14 × 26 (4)	6′ 6″	1 614	158	366	28	175	70.6
(m)	...	D. & S. E. (Ireland).	2-6-0	19 × 26	5′ 1″	952	134	162	20	175	48.5
(n)	...	B. & C. D. (Ireland).	0-6-4 T	17 × 24	4′ 0″	969	95	...	18	160	55.5

[656 .254 & 656 .222]

The dispatching system operated by telephone on the local lines in Czecho-Slovakia,

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With the railways, Austria handed over to Czecho-Slovakia, its methods of working them, especially that in use for controlling the running of trains.

The first object, when political independence was conceded, was to keep the trains running, but later, efforts were made to organise the system in order to adapt it to the changed traffic requirements which the new National State inaugurated, which differed widely from those of the old lines. After this, which the configuration of the old railway system made somewhat difficult, a third problem remained to be solved, no less important than the first two. It was necessary to restore the railway service so that it could run as regularly as before the war. This was found to be a heavy task, as much for the administrating departments as for the operating departments, and it was only at the end of the fourth year after political independence had been proclaimed that it was possible to think of introducing reforms and adopting methods of working similar to those in other countries.

A beginning was made on local lines where the traffic was light, because their simple construction and small staff enabled experiments to be made with a minimum of risk. Moreover, many of them were already fitted with telephonic communication which did not exist on the more important lines, and consequently reduced the expenditure for fitting up to a minimum.

Before describing the innovations that were introduced, it will be as well to briefly explain the methods used to work these lines, which do not differ greatly from those used on the important ones.

Each station is under the control of a station-master, who has charge of the whole staff. He is assisted by employees called *train dispatchers* who, besides looking after the operations relative to the running of the trains, keep the books and see after everything concerning the commercial side of the business. At all the smaller stations, and before the introduction of the eight-hour day, this work was done by the station-master himself. The arrival and departure of trains were entirely under the control of the station staff, as well as all the operations which took place at the station.

In spite of the number and diversity of his responsibilities, in the smaller stations the station-master could alone manage to do all that was required, and even then was not kept very busy. At the more important stations he was allowed an assistant, who relieved him when necessary. The eight-hour day law, however, brought about a radical change.

According to the Czecho-Slovakian

law, no employee may work more than forty-eight hours per week. However, if it is necessary for him to remain on duty, he may, if his work is not continuous, be allowed to exceed his allotted eight hours per day on condition that his actual work is reduced to six hours. Any extra time over the forty-eight hours per week has to be paid for, and in addition, each worker must have a break of at least thirty-two hours in his duties once a week.

As the train service on local lines connecting up to the main lines starts early in the morning and finishes late at night, it was necessary to have two *train dispatchers* at each station, the station-master and his assistant, even at those places where formerly the station-master alone was sufficient; also, in order to ensure that the 32 hours rest was provided, it was found necessary to provide substitutes, which increased the number of the normal staff by 30 %.

Attempts were then made to reduce these disadvantages. A solution which consisted in restricting the train times could not be entertained, as it would have reduced the usefulness of local lines in certain districts. Another radical and logical solution was then introduced which consisted in taking away from the station-masters and their assistants their control over the running of the trains, this important part of their duties being placed in the hands of other employees working to the instructions of a *dispatcher*.

This official is generally placed at the junction station at which the local line terminates, and from which he directs all the traffic. He is in communication by means of an ordinary telephone with the stations along the line, which as a rule are few in number, and it is the duty of the guards on the trains to communicate with this dispatcher during the stops at the stations.

This system has been successfully applied on a group of lines depending on the control from Louny and which consists of a total length of 79 1/4 miles, with a traffic of 230 000 train-miles; on another group of two small lines of 21 miles having a traffic of 53 000 train-miles, and on a branch line of 10 1/2 miles in length.

In a general way, the duties of a dispatcher are carried out by those who start the trains at the station from which the line is controlled, and the guards of these trains always inform them of their arrival and departure as follows :

a) from the departure and the terminal stations;

b) from stations specially chosen;

c) from a station preceding a station where there is a crossing;

d) from a station preceding a junction station if the delay has exceeded the time allowed for stopping;

e) from any station where the delay amounts to twenty minutes;

f) from any station where the dispatcher desires them to go.

The guards on the trains must inform the dispatcher of anything that may happen on the road likely to effect the safety of the trains.

Any telephonic messages received from the guards are entered at once a register kept at those stations in communication, and if any change is made in the point where trains are to cross or in the line at which a train will arrive, the guard writes down the messages received from the controlling station and has them signed by the engine driver.

The controlling station is also informed by the guard how the trains are made up,

and receives particulars concerning the sorting of the wagons at stations which are in communication with the sorting control office.

At through stations, the points are locked in their normal position, and the keys are taken away by the guard, who receives them from the dispatcher after disposing of this wagons. If the train has to proceed on to a line other than the usual one, the guard must see before leaving that the points are replaced in position and locked up. Emergency keys are kept in sealed boxes to be used in cases of necessity, and only by permission of the dispatcher.

Considerable economies in the staff have resulted from this method of working, and it is calculated than on the branch line mentioned above, the saving amounted to 54 000 crowns per annum.

After this practical experience, and in view of the favourable results obtained, it is proposed to extend the system progressively on lines where the traffic is not too heavy.

Special mention should be made, as far as further extension is concerned, of the Tábor-Písek line which is 37 1/2 miles long and which has only a small number of trains working it, but connects by express trains the western with the southern portion of the Republic.

At places on this line, however, where points for shunting purposes are concentrated, these are worked by pointsmen, except in a few cases where the guards are expected to assist.

[625. 143]

Permanent way phenomena, (1)

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(*The Railway Engineer.*)

One hundred years have elapsed since George Stephenson was faced with the choice of permanent way material for the Stockton and Darlington Railway. That choice lay mainly between the use of cast iron and malleable iron for the rails, and although the former were quoted at only £6 15 sh. per ton, against £12 10 sh. for the latter, Stephenson succeeded in convincing the directors that the additional cost was thoroughly justified. The rails, which were rolled, measured 15 feet in length, and weighed 28 lb. per yard.

Timber sleepers had long been in use : in fact, until 1797, when stone blocks were first introduced, they were employed in the construction of all wagonways. Stone was plentiful, and timber scarce, so that fort twenty-five years preference lay with the former.

In 1823, however, it was discovered that stone was not an economical material to employ in permanent way construction, especially when the quarry was far distant from the works. Oak blocks were frequently substituted in such cases, and these, cut from old ship timbers, represented an appreciable saving in cost. For forty years stone or oak blocks held their own, but gradually the timber sleeper found its way once into permanent way construction, primarily on account of the tendency of the blocks to rock on their bed, and they have ever since formed the foundation for the bulk of railway track the world over.

Steel rails first came into use in 1857 as the result of Henry Bessemer's success in producing it commercially at a cost which compared favourably with wrought iron. Fishplates were first employed in Britain in 1847, but were originally introduced on the Perth and Amboy Railroad of the United States seventeen years earlier.

The rail, the sleeper and the fishplate, all fundamental parts in the construction of permanent way in the early days of railways, are to-day equally fundamental. Vast strides have been made, it is true, in design and in metallurgy since Stephenson's time, but it is doubtful if any railway engineer could say that modern permanent way is all that it might be, and, despite the extensive knowledge which has been gained throughout a century of railway practice, there exist phenomena which have baffled the best engineering brains. With the exception of « creep », Stephenson apparently encountered little in the nature of phenomena, but « creep » he certainly did find, and in an effort to arrest it in 1816

(1) A paper read before the Association of British Engineers in the Argentine Republic, on 21 August 1923.

by the use of tapered joints, he failed, as many engineers have since failed. Apart from creep, most of the phenomena which confront the railway engineer to-day have come to light in comparatively recent times. In the hope that the many members of our Association whose duties bring them into direct touch with the ever-perplexing problems of permanent way design and maintenance will give us the benefit of their experience, it may be of interest to outline what has already been disclosed by others.

Rail corrugation.

Of all phenomena none, perhaps, has aroused greater controversy during the past decade than « rail corrugation ». From this trouble tramways are greater sufferers than railways; similarly, electric railways suffer more than steam-operated lines. Many explanations have been offered to account for the phenomenon, and the civil engineer, locomotive engineer, and rail manufacturer have all been assailed in turn as the prime contributor to the cause. Not a few engineers hold to the belief that in the process of rolling the initial corrugation is imparted to the rail through the « chattering » of the rolls, and that in service these corrugations develop. Whatever truth there may be in this, there is ample evidence to cast doubt upon it, for the rails which have passed through the same rolls do not universally develop corrugations subsequently. Again, there are cases in which rails develop corrugation when first placed in service, but instead of their developing further they are rolled out again, leaving a smooth, even surface. On tramways the pitch of corrugation is usually from 2 1/4 inches or 2 1/2 inches; on railways the range is greater, varying from a fraction of an inch to 30 inches.

There is a belief that small wheels and the resulting intense local pressure have much to do with the cause, and at first sight it would appear to offer the key to a satisfactory explanation, though not entirely, for all rails do not suffer. Quite recently the result of an experiment extending over six years on the London County Council Tramways by the Sub-Committee of the Municipal Tramways Association has been published, which supports the belief that intense local pressure is the primary cause of rail corrugation. The experiment was carried out in the L. C. C. subway below Kingsway, on a straight piece of level track, protected from weather and the effect of other traffic, and in view of a common belief that vibrations in the track contributed largely to corrugation exceptional means were taken to construct a solid, unyielding road. The tramway cars were mounted upon two four-wheeled bogies, the wheels of which measured 31 3/4 inches and 21 3/4 inches, and their total weight (empty) was 14 1/2 tons; the speed, 20 miles per hour. The rails developed corrugations, and after six years it was concluded that vibration had little or nothing to do with it, and that the cause was the heavily loaded wheels, which, rolling along the surface of the rail, gives rise to stress in the material in excess of its elastic limit.

Grinding action of wheels.

The theory that corrugation is caused by the grinding action of wheels relatively small in diameter, and aided in the case of a tramway by the presence of dust, has found favour with several eminent engineers, and is probably in part a contributory cause. Applying this theory to railways whose tracks are less rigid than tramways, but where axle loads and speeds are much greater, rail corrugation is certainly found at level crossings where grit is prevalent, but elsewhere it seems to defy definite lo-

cation. A few years ago a well-known English railway engineer stated that the conditions ruling on the line under his charge were.

a) That corrugation originated on falling grades;

b) That in tunnels it was confined to dry places;

c) That on falling grades it died out on approaching a station;

d) That it never occurred between platforms.

The line was steam-operated, and the facts seemed to indicate that corrugation was caused by the goods trains not fitted throughout with the vacuum or the Westinghouse brake. Here the train runs down the incline, with the locomotive wheels and the wheels of the guard's van braked. In such a case, momentary locking of the wheels takes place, and intense lateral pressure is set up, aggravated by sanding beneath the tyre. On reaching the foot of the incline the brakes would be released, so that on this reasoning items (*a*) and (*c*) would seem to hold. On passenger trains all wheels are braked, and though stops are made at all stations the lateral pressure exerted by a braked wheel is less than in the case of the goods train.

This would seem to account for the absence of corrugation between platforms. But the evidence does not end here, for another British railway engineer, reporting his experience on the line under his care, states that where passenger trains alone are run, and at high speeds, corrugation is found on a rising grade, and that corrugation occurs most where trains run freely without brakes, or with brakes slightly applied. Further, on fast rather than slow lines corrugation is more pronounced. This evidence is complicated by another engineer of the same line, who states that never does a rail corrugate on a gentle rising grade. This statement has been repeated by others, but it is not the writer's experience.

Another engineer has stated that rails containing 0.55 % of carbon and less than 0.08 % of phosphorus never corrugate; but again, the writer can disprove this. Tests made upon rails which have been in actual service disclose a hardening of the metal along the table which may reasonably be attributed to a form of cold rolling imparted by the wheels. A further test upon a corrugated rail discloses still harder metal upon the crest of corrugation.

Mr. Sellon, in his excellent paper to the *Institution of Civil Engineers* (vol. CXVII), says : « It seems evident that corrugation is set up by intermittent variation of wheel pressure or vertical vibration, but how the vibration is set up, why it persists, and why successive vehicles fall into step over corrugated lengths, there is great diversity of opinion and conflict of evidence. »

A very satisfactory explanation of the intermittent variation of wheel pressure has been given by an officer of the London Midland and Scottish Railway. The cause is attributed to chattering set up between the axleboxes and hornblocks, combined with horizontal surface friction. Side play permits the axlebox to strike the back slide and rebound to the forward slide, thus producing the condition conducive to corrugation. This takes place at each rail joint, and is aggravated by the application of the brakes, which momentarily lock the wheel.

Admitted that there are exceptions, it is generally recognised that corrugation is more marked where brakes are applied, and this is confirmed by the case of tramways, where brakes are much more frequently applied, the wheels small, and the rails grit covered.

Rail corrugation on underground railways.

Against this comes the case of the Baker Street and Waterloo, Charing Cross and Hampstead, and Great Northern and Brompton Railways of London, which were opened to service nineteen years ago, and on which rail corrugation has never been known, despite frequent application of brakes and small wheels. The track is of somewhat unusual construction, the sleepers resting upon a concrete bed over a width of about 3 ft. 10 in., leaving a short cantilever over which the rails are carried. Ballast fills the space intervening between sleepers and below the cantilevered ends, so that a certain measure of elasticity is always attained. So great is corrugation on other lines of the London Underground Railways that the rails have to be removed periodically from the track, and planed down to an even surface.

Argentine experience seems to point to the fact that (*a*) corrugation is more pronounced where brakes are applied, (*b*) that their pitch seldom exceeds 2 inches, (*c*) that the corrugations once formed never disappear, and (*d*) that high carbon rails corrugate quite as much as rails of lower carbon content. It is doubtful if the phenomenon can be traced to any single cause, but rather to a combination of causes, the principal factor being the slip produced by the momentary locking of the wheels by the brakes. Other contributory causes are probably the presence of grit, whether from « sanding » or spread over the rails at level crossings, and intense local pressure between wheel and rail : in a measure, the result of small diameter wheels. There are cases, of course, which respond to none of these, but they are very exceptional, and can only be treated on their own particular merits. As a general rule corrugation occurs where these three factors hold.

The phenomenon is not likely to disappear as years go by; on the contrary, railway engineers must be prepared to see it develop, and any new light which can be thrown upon this destructive action, which has provoked so much controversy, will certainly be taken into full account.

Broken fishplates.

Though less unaccountable than rail corrugation, the case of broken fishplates has led to very considerable controversy, and several theories have been advanced in explanation of the cause. In the first place, the joint is always the weakest spot in the track, and it is seldom that the moment of inertia of the two fishplates combined exceeds 80 % that of the rail. In many cases it is much less, even as low as 33 %. In addition to this, many companies employing flat-bottomed rails deliberately notch the horizontal limb of the fishplates in order to engage the track spike, and so assist in arresting creep. Further, it is a well-known fact that when a rail joint is strained under traffic the rails and the fishplates take up quite different deflection curves. In addition to this, the fishplates twist : outward beneath the head at the centre, and outward at the base near the ends. The wider the angle of the fishing planes the more do the fishplates twist. Though the fishplates are often slotted to engage two or more spikes, it is almost a certainty that in the majority of cases the resistance to creep is not uniformly offered, and so great is the pressure that the spikes are driven out of vertical, thus splitting the timber. It is very evident, then, that in such cases far more is demanded of the fishplate than it is reasonable to expect.

Reports on fishplate fractures from

every part of the world indicate that the point most open to failure is the upper edge immediately beneath the joint, fractures through the slot taking second place. In the *Journal of the Permanent Way Institution*, vol. 39 (April, 1921), the subject of « Broken Fishplates » is dealt with in a short paper by Mr. H. C. Honeybourne. The author of the paper seems to strike wide of the mark when he attributes the phenomenon to the fishplates acting as cantilevers, and so failing in tension at the centre of the upper edge. That the rail ends act as cantilevers there can be no dispute, but the plate uniting them cannot assume the same action : in fact, as already stated, the rails and fishplates are known to take up different deflection curves.

American fishplate experience.

Mr. P. H. Dudley, a well-known North American railway engineer, stated at the International Railway Congress of 1900 that a belief formerly existed that the metal for fishplates should be soft and ductile, in order to encourage yield without fracture. Mild steel was accordingly employed, but after two or three years' service fractures occurred in large numbers, particularly in cold weather. The upper fibres of the plates were strained almost to their elastic limit both in tension and compression, and the repetition of stress a few thousand times resulted in the checking of the top edge, and the cracking from the top downward in thousands of cases. The use of the softer metal was abandoned, and a steel having a much higher elastic limit substituted, a change which reduced breakages of this nature to a very great extent. Nevertheless the trouble continues, and every day brings to the scrap-heap fishplates which have failed in this way.

An American company recently introduced a fishplate depressed at the centre, just in the zone where breakage usually takes place, the object being to relieve the plate of all load at the critical point. What measure of success has attended this experiment the writer is unable to say. Another effort which has been made to meet the case has found favour more perhaps in Europe than elsewhere. This is the use of unsymmetrical fishplates, the outer plate having a bullhead along the upper edge, or else an upper limb. Similar treatment in the case of the inner plate is, of course, impossible, owing to the path of the wheel flange. Reports from Europe on the use of this mode of fishing do not appear to be very satisfactory. The two plates do not act in unison, the lighter yielding to the heavier, which assumes the bulk of the work. The joint twists more than would otherwise be the case, and the heavier plate is often found to be unequal to its task. As regards fractures through the spike slot, these occur with greater frequency where the corners are square, but are nevertheless frequent where the slots are properly radiused.

Again, examining the vertical deflection of the rails at the joint, depression of the joint sleepers in the first instance is caused by the passage of the wheels from the trailing to the facing ends, resulting in the premature displacement of the ballast, and this is augmented by flat wheels. In the case of short rails hog backing results from this depression at the joint; in long rails deflection is confined to the ends; but whether the rails are short or long, the fishplates are called upon to resist this movement.

It would seem that the failure of the fishplate at the centre is due to constant hammering upon the upper fishing planes, combined with relative slipping between rail and plate, and that failure through the slot is due primarily to the creep of the rails. If this is the explanation, the remedy seems to lie in reducing the angle of the fishing planes

to 1 in 4, in suppressing the slots, in giving as broad a bearing as possible over the upper fishing plane, and in the employment of a tough steel of high tensile strength.

Railhead deformation.

Another example of premature destruction is often seen along the gauge line of the rail-head, extending for several inches on either side of the joint. The first impression of the case suggests that the rail cants outward at the joint, and that the wheel rolls over the inner edge. However carefully one investigates the various deformations of the sleeper, the rail, and the rail-joint, it is difficult to account for any combination which could place the rail in such a position as to explain this particular case of local abrasure.

Though no definite explanation of the cause seems to have been advanced, it is probable that it lies mainly in the creep of the rails. The spike with which the rails are fastened has little to commend it apart from its low cost, and quite fails to hold the rail longitudinally. The result is that the tendency to creep is resisted only at the joint where the spikes engage the slots in the fishplates.

The rail slips unchecked through the fastenings of the intermediate sleepers, and it is invariably the left-hand rail in the direction of traffic which travels to the greater extent. By degrees the joint sleepers are driven out of square, sometimes to the extent of 12 inches, or even more, pulling in the gauge of the track as a result. A travel of 12 inches would reduce the gauge by 1 inch if the spikes held. With a track reduced in gauge at every joint, the wheel flange strikes a sharp glancing blow upon the side of the rail-head, resulting in the short line of wear so often noticed.

Checking or rebating of sleepers.

There is yet another phenomenon which is far from easy to explain satisfactorily : this is the checking or rebating of the sleeper by the rail foot at certain points on the track. It is not merely a fraction of an inch, but very frequently several inches. That a red quebracho sleeper is unable to sustain the pressure transmitted through the rail base may be discountenanced. Its ability to do so is clearly established in practice, and, furthermore, cases are quite common in which not only the rail base but also the horizontal limb of both fishplates have together rebated the sleeper. To localise the points at which the phenomenon is most apparent, unpaved level crossings, the points at which engines are accustomed to stand, and zones of indifferent drainage, seem to hold the principal conditions conducive to the cause. Grit and water are probably the two contributing factors, but if these could be prevented from entering the rail and the sleeper no damage to the timber would result.

The partial extraction of the spike alone could permit the intrusion of gritty mud, and once the grip is released the rail is free to hammer upon its seat, the water and grit together lending the medium which disintegrates the timber. A small check is created, and the spike is re-driven to compensate for the loss. The limit to which a spike can be re-driven is not great, and soon the grip on the rail foot is entirely lost when the rail becomes free to hammer the timber. A spike well driven into red quebracho can be extracted by a pull of about 11 000 lb., but the same spike re-driven will start again under a pull of about 7 500 lb.

In searching for a remedy, it is not always expedient or even possible to remove the conditions which bring about the presence of grit and moisture. This leaves the rail fastening or the

sleeper itself open to study. Why the spike should draw at all is a matter which calls for a little investigation. Take the case of a well-packed sleeper with the ballast along the centre line of the track lightly filled, or entirely removed; the zone of pressure is actually very limited, and is not more than 15 inches on either side of the rail : 12 inches is probably nearer the mark. With a sleeper 9 feet long on a track of 5-ft. 6-in. gauge, the extremities would lie beyond the zone of pressure until traffic caused the ballast to yield, when the sleeper would become end-bound and would deflect under the load, causing the rail to twist and the spike to start, and this is aggravated by the wave motion of the rail. A long controversy took place on the subject of correct sleeper length at the International Railway Congress some years ago. It was argued by two French engineers (dealing with standard gauge) that short sleepers, 2.20 m. (7 ft. 2 5/8 in.) in length, distributed the load more evenly over the ballast than sleepers 2.75 long (9 ft. 1/4 in.), which is common British and German practice. It is also Argentine practice, despite the greater gauge. The arguments opposing the use of short sleepers are mainly directed against their unfavourable influence on the track, especially where the depth of the ballast is stinted. A sleeper is more unsteady when the pressure over the ballast varies appreciably, and this is the case with short sleepers rather than with long.

To prevent the extraction of the fastening it is necessary to reduce deformation of the entire track structure to a minimum, or else abandon the spike for a fastening which does not rely upon friction with the timber for its resistance.

The standard sleeper in use on broad gauge railways in Argentina has a low moment of resistance only 576 cm^3 (35.15 cubic inches) and a stiffer and stronger track would result if 1 cm. (3/8 inch) were added to the width and 2 cm. (3/4 inch) to the depth, making up a section 25 cm. (10 inches) by 14 cm. (5 1/2 inches) with a moment of resistance of 816 cm^3 (49.80 cubic inches).

Even steel sleepers are not immune from checking. It is difficult in the first place to keep the fastenings tight, and when they are not so the rails chatter. If the fastening is neglected the nuts rust round the thread, when tightening becomes almost impossible, and the rail hammers freely upon the surface of the sleeper.

Rail battering.

There is yet another phenomenon which confronts the railway maintenance engineer : this is the local battering of the rail table a few inches beyond the joint on the facing rail. The point is usually clearly defined, and is uniformly located on each rail, though the position varies somewhat on different railways. The metal appears to be battered, leaving a cavity, and giving the rail a wider table than the normal. The explanation is probably to be found in relative vertical movements of the trailing and facing ends of the rails at the joint, a feature which can never be eliminated, but only mitigated by sound packing and effective fishing. The wheel on approaching the end of a rail causes local depression, which increases until the actual joint is reached. The facing rail, though dragged down by the fishplate, presents a step to the oncoming wheel. The wheel leaps this step and rebounds upon the table, the spot being determined by speed, relative efficiency of fishplates, and the condition of the joint generally.

Rail creep.

With the sole exception of corrugation there is no more bewildering phe-

nomenon connected with permanent way than creep. Much has been written on the subject during the past thirty years, but, despite all theory and observed fact, the subject is still open to controversy. To railwaymen anxious to pursue the subject more closely the writer would refer them to the Paper contributed by Mr. Frank Reeves to the *Institution of Civil Engineers* in 1917 (vol. CCV). It is beyond question that creep is more pronounced in the Argentina than in Britain, and the reason lies mainly in the ineffective fastening of the flat-bottomed rail as against the carefully chaired and keyed bull-headed rail. Further, the range of temperature in the Argentina is greater than in Britain.

The spike as a rail fastening exerts very little pressure upon the flange when driven into a red quebracho sleeper. In the first place a hole is bored, and the corners of the spike alone grip the timber; secondly, the wave motion of the rail, together with the tendency to twist, causes a slight extraction. To offset this weakness in anchoring, resort is frequently made to check creep by slotting the fishplate in order to engage the spikes in the joint sleepers. As previously stated, the practice has little to commend it, for the fishplates are already overburdened in taking care of other loads, and are inadequate even to meet these.

Creep is nearly always in the direction of traffic, and though it takes place despite temperature, it is nevertheless more pronounced during hot weather. Falling grades are slightly conducive to it, but the direction of traffic will cause the rails to creep even on a rising grade, and is a much more powerful factor. Many engineers contend that creep is more pronounced on a yielding roadbed when the wave motion of the rail is intensified. Be that as it may, rails creep over bridges, and the bridges themselves creep unless adequately anchored. There are engineers also who affirm that creep is greater on a hard, unyielding roadbed, and as such opinions are the result of personal observation they cannot be ignored; but however well the track is packed the wave motion is always present, and deformation of the rail is probably the prime factor in causing creep. In addition to this, the wheel load is also a powerful factor, and to a great extent also temperature plays a part.

Contributory causes.

As in the case of corrugation, there is probably no single cause to account for creep, but rather a combination of causes. It has been stated that where corrugation takes place, creep as a rule does not, and *vice versa.* If this be so, the inference is that a yielding road is conducive to creep. Rails of light section creep more than those of heavier type : this strengthens the belief that a yielding track offers less resistance to creep than a track of rigid construction. Under the influence of a rising temperature the rails expand, and if the fishplates are so tightly bolted as to impede free expansion the track kinks, unless the weight of traffic is sufficient to relax the hold at the joint; but the rails, under such conditions, will not regain their former position when the temperature falls. Many railway companies, realising this, oil the fishplates or smear the fishing planes with grease, in addition to slacking back the bolts slightly in the summer months. The objection to the use of grease is that under pressure it is squeezed out and does not fulfil its purpose, and altogether the work calls for considerable care.

The two rails of the track seldom creep uniformly : one or the other takes the lead for reasons difficult to explain, for observations on double track are completely upset by observations on single track. The writer's personal

observations are that the left-hand rail in the direction of traffic is that which creeps to the greater extent. On double track this might be attributed in a measure to the greater yield of the road-bed, since the ballast is looser along the edge than in the six-foot way; but the case of single track upsets this theory, for the left-hand rail travels in the direction of traffic whether it be outward or inward bound.

In 1904 a Dutch engineer, after much investigation, stated that he had noticed that, in the case of locomotives in which the leading crank was on the right-hand side, the tyres of the wheels on the left-hand showed slightly greater wear, and the engine, in consequence, leaned to the left. With the leading crank on the left-hand side, tyre wear was greater on the right. Whether this be the case or not, the tracks upon which the writer has studied creep have carried engines with the leading crank on the right.

Creep is much less noticeable on an earth-ballasted track, and Mr. A. C. Renton, formerly chief engineer of the Buenos Ayres Great Southern Railway, found that banking the ballast to the head of the rail had been instrumental in checking it. From this it may be inferred that if a rail be protected against a wide range of temperature, creep is greatly minimised. Even in England, where the range of temperature is less than in Argentina, it is sufficient to cause a variation in length of track of 41 inches per mile.

Whatever the cause or causes of creep may be, a rigid, wellpacked road with anti-creep devices, as distinct from fish-plate slotting, is of first importance. To shield the rail from great ranges of temperature is hardly less important, and, lastly, a better rail fastening than the spike affords is desirable where traffic is fast, heavy and frequent. That the locomotive engineer is not entirely blameless in the matter is a belief long held by many railway engineers, but it is difficult to measure his responsibility in the matter, and still more difficult to define the nature of the charges against him.

Roaring rails.

Another phenomenon which has perhaps received less consideration than any other is the formation or development of galls on the rail table. These commence with a small black spot, and spread out for an inch or more into a patch of deformed metal, which ultimately disintegrates and forms a cavity. In certain cases a rail develops one or two galls only; in others many of them, so that when traffic passes a roar takes place, from which the term « roaring rails » has come to be applied. The case is quite distinct from corrugation, an examination of these galls disclosing a series of longitudinal fissures, divided up transversely into a series of minor cracks. Beneath the damaged area lies a distinct plane of cleavage, the surface presenting a slightly crumpled texture. Frequently the film of metal can be lifted up with the fingers alone, or with the point of a penknife.

The number of cases which have been brought to the writer's notice are not very numerous, but all are very marked. Those on double track are more often found on a rising grade, and the left-hand rail in the direction of traffic is the rail which shows the greater susceptibility to the phenomenon. At first sight it would appear that the trouble is caused by the locomotive of a heavy train starting on the bank after a signal check : in fact there are occasionally indications corresponding to the positions of the driving wheels, but these are confined to one rail only, the corresponding impression of the wheels on the opposite rail not being apparent.

Further, the stretch of track affected is too long and too remote from signals for it to be assumed that the locomotive

could come to rest at any point upon it. On single line the phenomenon appears on both rising and falling grades, near signals, and far from signals.

The writer recently noticed the same defect on the Transandine Railway, where it is accounted for by the locomotives when pushing the rotary snow plough on the adhesion sections of the line. When the plough strikes an extra deep or hard snow bank the driver opens up the regulator, and the coupled wheels, rotating freely on one spot, grind out local cavities. Without expressing any decided opinion as to the cause, this to the writer seems to lie mainly in the composition of the rail itself. Horizontal fissures probably exist in the head before the rail is placed in service, and the heavier traffic conditions which rule on a rising grade bring about the breakdown of the thin film of metal which overlies the seam.

The writer trusts that what has been said may induce divisional engineers and those responsible for the maintenance of permanent way to place their experience of the many phenomena connected therewith at the disposal of the Association.

[625 .61 (.45)]

General rules (approved by the Ministerial Decree of the 27 March 1923) for the new railways and tramways leased to private companies which may be run over by goods wagons of the Italian State Railways.

Fig. 1, p. 156.

(*Giornale del Genio Civile.*)

Lines and installations, fixed and rolling stock, junctions with works, etc., of the railways and tramways recently constructed and worked by private enterprise, must satisfy the following conditions in order that the goods wagons running on the State Railways may be allowed to travel on them:

§ 1. — Width between rails.

The normal width between the inside edges of rails on straight sections of the line must be 1.445 m. (4 ft. 8 7/8 in.). In certain special cases a minimum width of 1.435 m. (4 ft. 8 1/2 in.) may be allowed on straight lines.

On curves with a radius equal to or less than 650 m. (32 1/2 chains), the spacing must be increased according to the dimensions given in table 1. An extra 5 mm. (3/16 inch) may be allowed for the width of the road when the lines are straight and on curves when the radius is 400 m. (20 chains) and above, and 3 mm. (1/8 inch) when the curves have a smaller radius.

§ 2. — Inclination of rails.

Rails, except those of the Phœnix type, should be inclined 1 : 20 towards the inside of the track, crossings and points being alone excepted.

§ 3. — Adjustment of the gauge where straight lines and curves meet.

The increase in the gauge on a curve should begin at the tangent point, and should proceed at the rate of one millimetre per metre up to the maximum allowed for the curve.

However, on the curve which joins up the switch rail of a turn-out with the crossing, the gauge corresponding to the radius of the curve should be reached midway between these points, and the necessary adjustment in the gauge should be made over the first half of the distance between the switch and crossing.

§ 4. — Superelevation of the outside rail of a curve.

The superelevation given to the outside rail of curves should be calculated preferably from the following formula in use on the State Railways.

$$h = \frac{eV^2}{0.127\ R}$$

in which

h = superelevation in millimetres;

V = speed in kilometres per hour given by the formula

$$V = \sqrt{\frac{V_1^2 + V_2^2}{2}}$$

in which V_1 and V_2 are the speeds in kilometres per hour of the fastest and slowest trains;

e = distance between centres of rails measured on the heads of the latter, in metres;

R = radius of the curve, in metres.

At stations where all trains stop, the above mentioned superelevation should be reduced by half.

No superelevation is given to curves on secondary lines, and the same may be said in general for lines branching off.

§ 5. — Joining up of superelevated rails.

The joining up of superelevated rails should be done progressively with a slope of 2 to 4 ‰ from the straight portion which precedes the tangential point of the curve.

If the straight portion lying between two curves running in opposite directions is not sufficiently long to obtain the whole of the superelevation, this may be continued on to a part of the curve; if the curves run in the same direction, the superelevation is maintained on the straight portion when the two curves have different radii.

In the case of branches on the main line, beginning with a curve and in which the line branching off comes from inside the curve, — an instance in which superelevation is recommended, — the latter should be applied to the two lines corresponding to the curve of the line run over at the highest speed.

§ 6. — Exceptions for tramways and connections to private works.

The rules given in paragraphs 2, 3, 4 and 5 are not insisted upon either in the case of tramways running along the ordinary roads or streets, or with connections with private works, on condition that the trains do not exceed a certain speed.

§ 7. — Level crossings and sections of lines on roads used by ordinary vehicles.

If at level crossings and portions of the line common with the public roadway, guard rails are used, or any other arrangement taking the place of guard rails, the distance between the running rails and the guard rails should be as given in table 2.

If the line is not fitted with guard rails, it should be so arranged as to give free passage to the wheel flanges.

TABLE 1.

Width between rails on the straight and in curves.

NATURE OF LINE.	Width between rails (in metres).	Super-width (in millimetres).
Straight lengths or curves with a radius over 650 m. (32 1/2 chains).	1.445 (4' 8 7/8")	...
Curves of 650 m. (32 1/2 chains) radius, or less, down to 500 m. (25 chains).	1.450 (4' 9 1/16")	5 (3/16")
Curves with a radius less than 500 m. (25 chains) down to 400 m. (20 chains)	1.455 (4' 9 1/4")	10 (13/32")
Curves with a radius less than 400 m. (20 chains) down to 120 m. (6 chains)	1.460 (4' 9 1/2")	15 (5/8")
Curves with a radius less than 120 m. (6 chains)	1.465 (4' 9 5/8")	20 (13/16")

TABLE 2.

Spacing between the running rail and guard rail on ordinary lines.

NATURE OF LINE.	Width between rails, in metres.	Width of space between running rails and guard rails, in millimetres.	Width of space at the ends of guard rails, in millimetres.
Straight length (special gauge)	1.435 (4' 8 1/2")	50 (2")	90 (3 1/2")
Straight length or curves to a radius of over 650 m. (32 1/2 chains)	1.445 (4' 8 7/8")	60 (2 3/8")	100 (3 15/16")
Curves to a radius of 650 m. (32 1/2 chains) or down to 500 m. (25 chains).	1.450 (4' 9 1/16")	65 (2 1/2")	105 (4 1/8")
Curves to a radius less than 500 m. (25 chains) or less, down to 400 m. (20 chains).	1.455 (4' 9 1/4")	70 (2 3/4")	110 (4 5/16")
Curves to a radius less than 400 m. (20 chains) or less, down to 120 m. (6 chains)	1.460 (4' 9 1/2")	75 (3")	115 (4 1/2")
Curves to a radius less than 120 m. (6 chains) . . .	1.465 (4' 9 5/8")		

§ 8. — **Curves.**

The radii of main line curves should, as a rule, be not less than 150 m. (7 1/2 chains).

On lines in stations, and in certain special cases on the main road, curves with a radius less than 150 m. are permitted, but these must in no case be less than 120 m. (6 chains) and must be run over at reduced speed.

Between two consecutive curves running in opposite directions, a straight portion must be interposed at least 30 m.

(98 feet) long. At stations and in special cases on the main line, this length may be reduced down to a limit of 10 m. (33 feet), speed being correspondingly reduced.

On those lines, where for exceptional reasons curves with a radius between 120 and 150 m. have been allowed and where the straight portion between curve and counter curve is less than 30 m., the Administration of the State Railways may disallow or restrict the running of certain classes of vehicles, each particular case being considered separately.

§ 9. — Minimum clearance allowed between fixed obtacles and the standard loading gauge.

On the Italian railways, it is necessary that a certain amount of clearance or space should exist between the standard loading gauge fixed normally to the ground plan of the line and the obstacles which exist on the latter. This clearance should not be less than those given in table 3, so far as this condition has not already been fulfilled by the application of the rules given in paragraph 4 of article 269 in the special chapter giving the legal requirements for railways conceded to private enterprise, tramways worked mechanically, and automobiles, approved by Royal Decree issued on the 9 May, No. 1447.

§ 10. — Strength of the road.

At the extreme limit of its wear, the road should have the necessary strength to carry axles loaded to 15 t.

The greatest tensile stress allowed in rails when at their limit of wear is 14 kgr. per mm² (19 912 lb. per square inch).

For calculating the unit of the maximum tensile stress, Winkler's formula should be used:

$$t = \frac{0.189 \times a \times G}{W}$$

in which

G = 7 500 kgr. in weight transmitted through the wheel;

a = maximum distance in millimetres between the centres of two adjacent sleepers if the road is not provided with carrying plates, or maximum distance between the edges of the carrying plates of two neighbouring sleepers if the road is fitted with carrying plates.

W = the moment of resistance, in cubic millimetres, of the rail at its extreme limit of wear.

§ 11. — Rails.

The weight of rails per linear metre should not as a rule be less than 30 kgr. (60.48 lb. per yard), nor their sectional dimensions less than the following :

Width of head.	57 mm. (2 1/4 in.).
Width of foot. . , . .	95 mm. (3 3/4 in.).
(when referring to Vignoles rails).	
Height of rail.	123 mm. (4 13/16 in.).

The length of rails should not as a general rule be less than 9 m. (29 1/2 feet).

In exceptional cases, a weight of less than 30 kgr. per linear metre (60.48 lb. per yard) may be allowed on condition that it is not less than 27 kgr. (54.43 lb. per yard) when fixed according to the conditions given in the following paragraph 12.

Rails fitted with the Phœnix groove are also permitted, providing that the groove has a depth of 41 mm. (1 5/8 inches) and a with corresponding to the space allowed between the running rail and guard rail, as given in paragraph 7 and table 2.

§ 12. — Laying of the road.

In laying the road, the number of sleepers used for each type of rail should

TABLE 3.

Minimum clearance allowed relative to the standard loading gauge on straight and curved lines.

Radius of curves, in metres.	Minimum clearance : a — On inside of curve, in millimetres.	a — On outside of curve, in millimetres.	b — On inside of curve, in millimetres.	b — On outside of curve, in millimetres.	*Remarks.*
From ∞ down to 250 m. (12 1/2 chains)	150 (5 29/32″)	150 (5 29/32″)	40 (1 19/32″)	40 (1 19/32″)	The meaning of the letters *a* and *b* refer to the spaces in a horizontal direction, see figure 1.
< 250 m. (12 1/2 chains) down to 240 m. (12 chains) . .	158 (6 1/4″)	160 (6 5/16″)	48 (1 29/32″)	50 (2″)	
< 240 m. (12 —) — 220 m. (11 —). .	177 (7″)	183 (7 3/16″)	67 (2 41/64″)	73 (2 7/8″)	
< 220 m. (11 —) — 200 m. (10 —). .	200 (7 7/8″)	210 (8 13/32″)	90 (3 1/2″)	100 (3 15/16″)	
< 200 m. (10 —) — 180 m. (9 —). .	228 (9″)	243 (9 9/16″)	118 (4 41/64″)	133 (5 1/4″)	
< 180 m. (9 —) — 170 m. (8 1/2 chains).	244 (9 5/8″)	263 (10 3/8″)	134 (5 9/32″)	153 (6″)	The spaces shown in this table should be adhered to not only on the curve, but at least for a distance of 8 m. (26 feet) before and after it. Beyond this distance they are joined up with the minimum space following a straight line over a further length of 15 m. (49 feet).
< 170 m. (8 1/2 —) — 160 m. (8 —).	273 (10 3/4″)	285 (11 1/4″)	163 (6 29/64″)	175 (6 29/32″)	
< 160 m. (8 —) — 150 m. (7 1/2 —).	283 (11 5/32″)	310 (1′ 3/16″)	173 (6 27/32″)	200 (7 7/8″)	
< 150 m. (7 1/2 —) — 140 m. (7 —).	339 (1′ 1 3/8″)	366 (1′ 2 13/32″)	229 (9″)	256 (10 5/64″)	
< 140 m. (7 —) — 130 m. (6 1/2 —).	403 (1′ 3 7/8″)	431 (1′ 5″)	293 (11 9/16″)	321 (1′ 5/8″)	
< 130 m. (6 1/2 —) — 120 m. (6 —).	479 (1′ 6 7/8″)	506 (1′ 7 29/32″)	369 (1′ 2 1/2″)	396 (1′ 3 19/32″)	
< 120 m. (6 —) — 110 m. (5 1/2 —).	569 (1′ 10 13/32″)	599 (1′ 11 19/32″)	459 (1′ 6 5/65″)	489 (1′ 7′ 1/4″)	
< 110 m. (5 1/2 —) — 100 m. (5 —).	676 (2′ 2 21/32″)	706 (2′ 3 51/64″)	566 (1′ 10 9/32″)	596 (1′ 11 1/2″)	

be such that the maximum distance a between the centres of two consecutive sleepers should not exceed that given by the formula:

$$a = \frac{t \times W}{0.189 \times G}$$

in which the terms are the same as those given in paragraph 10, and in which t must not exceed 14 kgr. per mm² (19 912 lb. per square inch).

If the rails used are heavier than 30 kgr. per linear metre (60.18 lb. per yard), the above formula should still be used for laying them down, though in no case the distance between the centres of the sleepers must exceed 1 m.

§ 13. — **Rail joints.**

Joining the rails together must be done by means of fish-plates fastened with at least four bolts and made to the patterns adopted by the Administration of the State Railways according to the class of the road.

§ 14. — **Fastening the rails to the sleepers.**

Rails should, on main lines, be supported by means of bearing-plates attached to each sleeper, both on the straight and on curves. On secondary lines, the use of these plates may be reduced to one half on the straight and on curves of more than 600 m. (30 chains) radius; on other curves all bearing points must be fitted with them. Greater latitude as regards the use of bearing-plates may be allowed as far as tramways, junction and station lines are concerned.

§ 15. — **Projection allowed for joints and rail couplings.**

The projection allowed in all methods of joining and coupling rails should be such that when the rails have reached their extreme limit of wear, there should be a clearance of 41 mm. (1 5/8 inches) below the rail level to allow for the free passage of the wheel flanges, as shown in figure 1.

§ 16. — **Sleepers.**

Wooden sleepers should have the following minimum dimensions:

Length	2.3 m. (7 ft. 6 in.).
Width.	0.22 m. (8 5/8 inches).
Thickness . .	0.125 m. (5 inches).

Metal sleepers should have a bearing surface of at least 2.30 m. × 22 cm. (7 ft. 6 in. × 8 5/8 in.), and their weight should not be less than 60 kgr. (132 lb.).

Reinforced concrete sleepers should satisfy the same conditions as those for metal ones.

§ 17. — **Distance between the centres of contiguous lines.**

The distance between the centre lines of two contiguous lines, either straight or curved, should not be less than the minimum figures given in table 4, as far as this condition has not already been fulfilled according to paragraph 2 of article 1 in the rules given for the fulfilment of the Act of the 27 December 1896, No. 561, with reference to tramways.

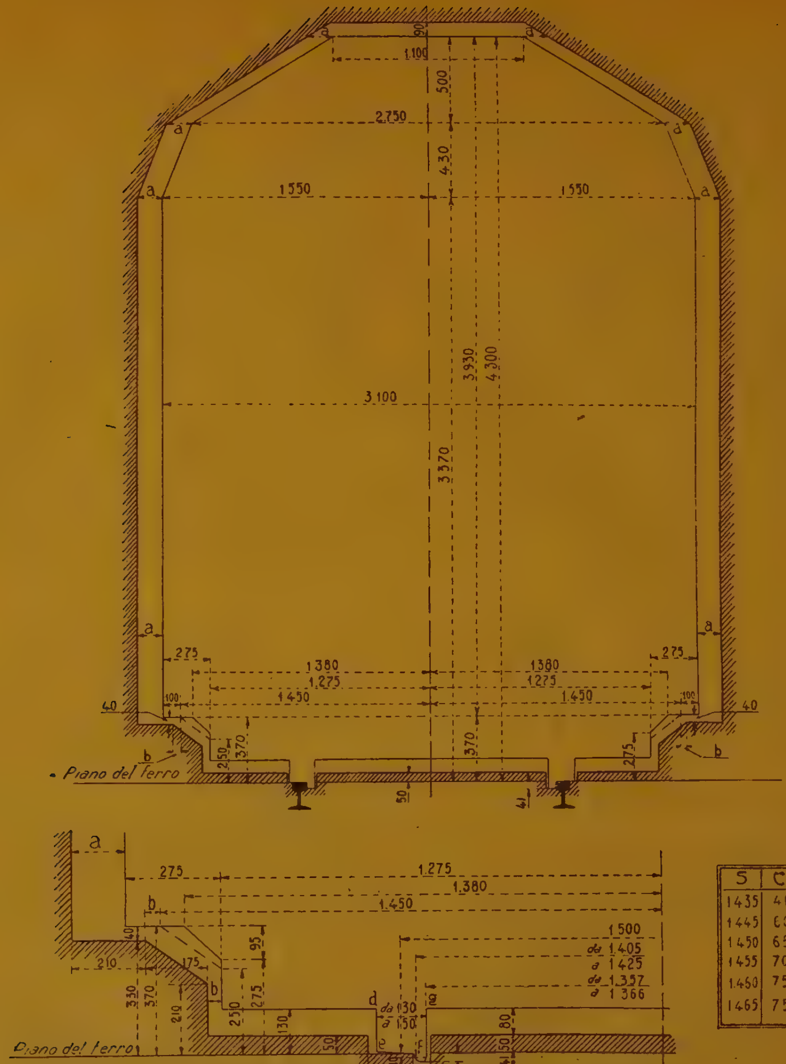
§ 18. — **Single and double branches.**

Curves joining up branches from the main lines should have a radius of at least 120 m. (6 chains).

A straight portion of at least 10 m. (33 feet) should be interposed between two curves running in opposite directions and joining parallel lines.

When these changes in direction lead into sidings, the connecting curves may be allowed a radius of not less than 100 m. (5 chains).

The free space allowed for tyre flanges between the far end of the points and the check rail should not be less



S	C
1435	40
1445	60
1450	65
1455	70
1460	75
1465	75

N. B. — The space *d, e, f, g* must only be occupied by the rolling parts.

GENERAL DESCRIPTION.

Fig. 1. — Limiting loading gauge showing the minimum free space allowed for fixtures on the road.

EXPLANATION :
- ——— Loading showing alterations in the bottom portion according to the « passe-partout gauge ».
- - - - - Modifications to the gauge suggested for the future.
- ////// Minimum profil for obstacles.

Explanation of Italian terms : Piano del ferro = Rail level.

TABLE 4.

Distance between centre lines of contiguous roads.

NATURE OF THE ROAD.	Gauge, in millimetres (in inches).	Increase in width of the six-foot of 2.12 m. (6 ft. 11 1/2 in.) in curves with a radius less than 250 m. (12 1/2 chains) in millimetres (in inches).	Six-foot (distance between the inside edges of the neighbouring rails of two contiguous lines, in millimetres (in inches).	Between the centre lines of the roads, in millimetres (in inches).
On the straight (special gauge)	1 435 (4' 8 1/2")	...	2 120 (6' 11 15/32")	3 555 (11' 8")
On the straight and in curves with a radius above 650 m. (32 1/2 chains)	1 445 (4' 8 7/8")	...	2 120 (6' 11 15/32")	3 565 (11' 8 3/8")
Curves with a radius of 650 m. (32 1/2 chains), or below, down to 500 m. (25 chains)	1 450 (4' 9 1/16")	...	2 120 (6' 11 15/32")	3 570 (11' 8 9/16")
Curves with smaller radii				
500 m. (25 chains) down to 400 m. (20 chains)	1 455 (4' 9 1/4")	...	2 120 (6' 11 15/22")	3 575 (11' 8 3/4")
400 m. (20 —) — 250 m. (12 1/2 —)	1 460 (4' 9 1/2")	...	2 120 (6' 11 15/32")	3 580 (11' 9")
250 m. (12 1/2 —) — 240 m. (12 —)	1 460 (4' 9 1/2")	18 (23/32")	2 138 (7' 5/32)	3 598 (11' 9 11/16")
240 m. (12 —) — 220 m. (11 —)	1 460 (4 9 1/2")	60 (2 3/8")	2 180 (7' 1 27/32")	3 640 (11' 11 5/16")
220 m. (11 —) — 200 m. (10 —)	1 460 (4' 9 1/2")	110 (4 5/16")	2 230 (3' 3 13/16")	3 690 (12' 1 9/32")
200 m. (10 —) — 180 m. (9 —)	1 460 (4' 9 1/2")	171 (6 3/4")	2 291 (7' 6 3/16")	3 751 (12' 3 11/16")
180 m. (9 —) — 170 m. (8 1/2 —)	1 460 (4' 9 1/2")	207 (8 5/32")	2 327 (7' 7 5/8")	3 787 (12' 5 1/8")
170 m. (8 1/2 —) — 160 m. (8 —)	1 460 (4' 9 1/2")	258 (10 5/32")	2 378 (7' 9 5/8")	3 838 (12' 7 1/8")
160 m. (8 —) — 150 m. (7 1/2 —)	1 460 (4' 9 1/2")	293 (11 9/16")	2 413 (7' 11")	3 873 (12' 8 1/2")
150 m. (7 1/2 —) — 140 m. (7 —)	1 460 (4' 9 1/2")	405 (1' 4")	2 525 (8' 3 7/16")	3 985 (13' 29/32")
140 m. (7 —) — 130 m. (6 1/2 —)	1 460 (4' 9 1/2")	534 (1' 9")	2 654 (8' 8 9/32")	4 114 (13' 6")
130 m. (6 1/2 —) — 120 m. (6 —)	1 460 (4' 9 1/2")	685 (2' 3")	2 805 (9' 2 7/16")	4 265 (13' 11 29/32")
120 m. (6 —) — 110 m. (5 1/2 —)	1 465 (4' 9 5/8")	868 (2' 10 5/32")	2 988 (9' 9 5/8")	4 453 (14' 7 5/16")
110 m. (5 1/2 —) — 100 m. (5 —)	1 465 (4' 9 5/8")	1 082 (3' 6 19/32")	3 202 (10' 6 3/32")	4 667 (15' 3 3/4")

Remarks. — These distances should be adhered to, not only in the curve, but also for a lenght of at least 15 m. (50 feet) before and after the curve. Beyond this lenght they must be joined up in a straight line to the minimum six-foot.

than 100 mm. (4 inches), with a distance between rails of 1.455 m. 4 ft. 9 1/4 in.) at the points. With larger distances between rails, this space should be increased by an amount equal to the extra width between rails above that mentioned above.

In cases where Phœnix rails or guard rails are fitted in the portion immediately preceding the points, the above-mentioned space may be reduced to the width of the groove in the Phœnix rail or to that of the space between the running rail and guard rail, providing that the toe of the point offers no obstruction which might strike the wheel flanges.

The width between rails should be 1.44 m. (4 ft. 8 5/8 in.) at the heel of the points, and 1.435 m. (4 ft. 8 1/2 in.) at the crossing.

The space between the switch rail and the stock rail should be 60 mm. (2 3/8 inches) and that between the running rails and guard rails opposite the crossing 40 mm. (1 5/8 inches).

§ 19. — Junction crossings and ordinary crossings.

The preceding regulations are valid for the width of the space between running rails and guard rails of ordinary and junction crossings.

The tangents adopted for crossings should not exceed 0.15.

With double crossings, the « hare's feet » should be raised 50 mm. (2 inches).

§ 20. — Clearance marks.

The mark denoting that there is sufficient clearance between two lines forming a junction crossing or intersection should be placed at the point where the six-foot or distance between the inside edges of the neighbouring lines is 2.12 m. (6 ft. 11 1/2 in.). If these lines are curved to a radius less than 250 m. (12 1/2 chains), this distance should be increased by the amounts shown in column 3 of table 4.

§ 21. — Couplings and buffers of rolling stock.

Coupling and buffer apparatus used on private lines should be similar to those used on the State Railways' rolling stock and satisfy in every respect the regulations issued by the railway technical co-ordination department.

§ 22. — Lines with double gauge.

Lines laid with a double gauge on which traction is provided for by means of narrow gauge locomotives, the construction of the line should, except in special cases to be considered separately, be so arranged that the tractive effort takes place along the centre line of the standard gauge, and always the same height above this road.

The regulations issued by the railway technical co-ordination department relating to coupling and buffer apparatus apply also to these lines.

NEW BOOKS AND PUBLICATIONS

[385. (09.1 (.42), 385 .4 (.42) & 385. (04]

SIMNETT (W. E.), M. B. E., Assoc. Inst. C. E., Railways Amalgamation Tribunal, Late Director, Ministry of Transport. — **Railway Amalgamation in Great Britain.** — One volume in 8vo (8 3/4 × 5 1/2 inches) of 270 pages and 4 maps. — 1923, published by the *Railway Gazette*, 33, Tothill Street, Westminster, London, S. W. 1. — Cloth, price : 15 sh. net.

This work forms the only connected and authoritative account in existence of the course of railway amalgamation in Great Britain from the earliest years up to the completion of amalgamation in 1923. The full original documents reproduced in the Appendixes will be found indispensable to all students of the important and complex economic, financial and other problems involved, to legislators and public officials and to railway directors and officers at home and in all parts of the world; as well as to that wider public which takes an intelligent interest in the problems of what must ever be one of the most important factors in the economic life of any country — its transportation system.

The author is exceptionnally well qualified to treat of this subject, being an officer of the Tribunal entrusted by Parliament with the task of amalgamating the railways of Great Britain, and possessing a first-hand and inside knowledge of the questions with which he deals. Added to wide experience gained before and during the war, he was a director of the Ministry of Transport from its inception, and watched critically the development of the post-war transport situation both in this and in other countries.

The book describes all phases of railway amalgamation in this country — its early beginning, almost contemporaneous with the introduction of railways and development up to 1914; Government possession and control of the railways during and after the war; the establishment of the Ministry of Transport; the railway agreements and the compensation settlement; the introduction of the Railways Bill; the provisions of the Act; the constitution and work of the Amalgamation Tribunal; the distribution of the £60 000 000 in compensation and the completion of amalgamation. A description is given, with maps, of the four great systems now existing in Great Britain and questions of organisation and further development are touched upon.

An especially interesting chapter is that dealing with the *railway problem in other countries,* both in Europe, America and India, whence it will be seen that the question is of world-wide interest and importance. Indeed, this work should be found of interest not only to a wide public in Great Britain itself, but perhaps in an even greater degree to students of railway economics in other countries, especially the United States of America, where similar problems are now being encountered.

In conclusion, the author deals briefly, but thoughtfully, with the future of railways in this country. The Appendixes, consisting of original documents, are especially full and valuable, and will

render the book indispensable as a permanent work of reference. The work is also supplied with a bibliography and a good index.

[621 .13 (02 & 385. (04]

SAUVAGE (Ed.), honorary chief engineer of the French State Railways, professor at the « Conservatoire national des Arts et Métiers », laureate of the Institute. — **La machine locomotive (The locomotive engine)**, 7th edition. — One small volume in-8vo (7 3/4 × 5 inches), of xvi + 412 pages, with 342 illustrations. — 1923, Librairie Polytechnique Ch. Béranger, 15, rue des Saints-Pères, Paris, and 8, rue des Dominicains, Liége. — Price : 31.25 francs net.

It is a somewhat difficult task to write a book giving a sufficiently complete description of the various parts of the locomotive so as to make their working clearly understood by the drivers and the stokers. The technical literature on the subject includes a certain number of works of this kind, and amongst them, Mr. Sauvage's book, which is well known to most French readers, occupies a prominent position. The successive editions that have been published, the seventh of which now appears, are proof of its success, and shows the desire of the author to keep his work thoroughly up-to-date as regards the latest improvements.

The plan of the book, quite logically conceived, is on the same lines as the previous editions. In a first chapter entitled « Generalities » the author, by giving practical examples or showing simple mechanical contrivances, explains the meaning of the elementary terms in mechanics, such as force, work, power, etc., a knowledge of which is necessary in order to read the book with profit. Substantial information is added with regard to fuel and combustion, material used in the construction of locomotives, train resistance, calculations of speed, etc.

The real description of the locomotive itself is contained in three chapters, which deal successively with the boiler, the mechanism and the vehicle (framing, suspension, wheels). The three following chapters deal with the various types of locomotives, the construction of tenders and the means used for stopping trains. The two last chapters are devoted to the maintenance of locomotives and the organisation of the staff in the running sheds.

The descriptions given are made clear by means of numerous sketches, general arrangements and drawings of details showing the construction and methods by which the different parts act. With each description the author also gives the reasons for adopting the different arrangements employed, explains their use and how they are worked, the precautions that shoud be taken and material to use.

In the chapter relating to boilers, the accessory and safety apparatus are dealt with all the thoroughness their importance requires. Amongst the latest improvements we may mention : rocking firebars, water tubes supporting the arch, expansion stays, improved injectors, Coale's safety valves, superheaters and water heaters.

The chapter dealing with mechanism contains, as well as a description of the various parts, a complete study of valve gearing, a critical examination of the characteristics of the mechanism of the principal systems in use, and an analysis of the various phases of the working of the steam. It may be seen from the diagrams the influence due to speed, the position of the reversing screw or lever

and the opening of the regulator. All the auxiliary apparatus are carefully described : regulators, lubricators, relief and by-pass valves, reversing gear, starting apparatus for compound locomotives, etc.

We cannot undertake to summarise or analyse the whole of this remarkable work. To do this, it would be necessary to pass in review the whole locomotive in detail and each sentence would have to be taken into consideration. We will limit ourselves therefore to briefly calling attention to the following : in the chapter « Framing, suspension, wheels » a study of the distribution of the weight on the axles and drawings of the various kinds of bogies and pony trucks; in the chapter « Means of stopping trains » a description is given of the apparatus used in the compressed air and vacuum brakes and also that by the method of retarding the train by reversing the engine; chapter V, which gives numerous diagrams and photographs of various locomotives, some of which are of quite recent design.

Most of the illustrations showing details or parts of locomotives are taken from the designs used by the French companies, but this does not detract from the value of the work as far as foreign readers are concerned. Among the new sketches published in this edition, a somewhat large number are reproduced from the drawings made at the Central Offices for the co-ordination of design of railway material, and consequently add very materially to the interest of the work.

E. M.